

CHEMICAL & METALLURGICAL ENGINEERING

McGraw-Hill
Publishing Company, Inc.
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Editor

Volume 33

New York, October, 1926

Number 10

Severe Service

IT is usually the baffling problem that most invites solution; that intrigues curiosity and challenges ability. Thus aviation grips the imagination more than the pony express; the ascent of Everest commands more daring than a tour de luxe; radio taxes the ingenuity beyond the demands of wired communication. Likewise synthetic industrial products, chemical reactions at high temperatures and pressures, the development of metals, alloys and refractories for abnormal conditions, the design of equipment for exceptional performance, all involve problems that command the utmost resources of science and engineering.

CHARACTERISTIC of the chemical engineering industries is the fact that at some point in each process materials of construction and equipment are subjected to severe service. Weak links develop in the chain of operations. Repairs and replacements may be excessively high; yields unprofitably low. Efficiency suffers and costs mount accordingly. But for the lack of more serviceable materials and more effective processes, production might be cheaper, legitimate profits higher and distribution much wider. The crux of the problem is usually apparent, and the point of severe service becomes the object of attack to effect improvement.

IN the hope of making a modest but timely contribution to so extensive a subject the editors of *Chem. & Met.* have compiled this Severe Service number. Probably two hundred contributors have made possible whatever degree of success has been attained. To them are due the thanks of chemical engineers however occupied, for it has long since been recognized that these men have many problems in common and that a solution

first discovered in one industry is adaptable in others. The final products of these industries may be wholly unrelated, yet the processes will involve the same principles, similar equipment and materials of construction. Hence the contents of this number make a wide appeal regardless of occupation.

CORROSION continues to be the *bête noir* of chemical engineers, and hence metallurgy looms large on their horizon. To the familiar processes of atmospheric and soil corrosion with which they have to contend must be added the phenomena of chemical attack which are as varied as chemical production itself. No panacea exists. Temperature, pressure and chemical reaction in different combinations call for special materials for special purposes. Such problems afford some of the finest examples of severe service. Using the most suitable metals and alloys now available, chemical production proceeds apace but with constant search for something better.

OTHER phases of the subject have not been neglected. Rubber, ceramic products, cement, phenol resins and pyroxylin plastics play their part in meeting severe service conditions. The hazards of chemical manufacture impose unusual requirements on safety measures to protect life and property, and the extent to which these are successfully met is reflected in the relatively high degree of safety in the explosive industry. The problems of erosion also have received attention, and a miscellany of unusual plant conditions have been brought together from numerous sources. The subject has by no means been exhausted, nor does its treatment measure up to the ambitious program originally outlined, but the result is offered as a practical effort toward solving some of the problems of severe service.

Good Bearings Aid Economical Operation

DIRECT results in increased production are realized in industries like the manufacture of rubber and paper when machines are speeded up by the application of improved bearings. These results are so dramatic that the other advantages obtained—longer life of machines and accessories, better and less expensive lubrication, lower maintenance and repair costs—are overshadowed. Hence the application of improved bearings is becoming well nigh universal in such industries.

But in the many industries where increase in production from such improvements is at best slight and the advantages realized lie mainly in the other factors, change in bearing practice has been slow. The advantages to be obtained through an increased investment in bearings are not so evident and it is perhaps natural that management should be slow to spend the money necessary to make the improvement.

The expenditure involved is, however, relatively small and is often justified by power saving alone. And when one considers the relatively high cost of equipment throughout the chemical engineering industries it is patent that any increase in the life of equipment will justify the use of improved bearings in many cases where they are not as yet applied.

In view of these facts, some of which are well brought out by examples given on pages 638 to 641 of this issue, it would seem the part of wisdom for plant managers to make a careful review of bearing practice in their plants. We are confident that there is hardly a chemical engineering plant in which some worthwhile improvement cannot be made through the use of better bearings.

Frequent Inspection During Severe Service

HENRY FORD is recently reported to have doubled the inspection staff at Highland Park as the first step in stamping out the growing symptoms of an epidemic of inefficiency. Inspection is good medicine for many other industrial ills, however, and its value should not be underestimated, particularly in the plant that faces the problem of severe service in its manufacturing operations.

The management of one of the largest petroleum refineries in this country takes pride in the fact that it has never had a single major accident in the operation of its high-pressure cracking equipment. During the same period a number of less fortunate refineries with fewer stills and apparently more favorable conditions have met with serious fires or explosions that have exacted a heavy toll of life and property. The good fortune of the first refinery is commonly ascribed to a plan of inspection that appears to be as unique as it is efficient. The inspection staff in this plant acts as an independent department, responsible solely to the management. In this respect it ranks on a co-ordinate basis with production, engineering and plant construction. When a battery of cracking stills is shut down for any cause, the production department immediately relinquishes control to the inspection staff. Before the battery can be put back into production, it must have

passed a rigid inspection and have received the written approval of the inspection department. And as often as not this approval is not forthcoming until a burned tube or a corroded vapor line has been replaced. Visual inspection is not allowed to suffice; the metal is hammered and, in the case of the reaction chambers and certain other equipment, drill holes are made at points of suspected weakness and the thickness of the metal is measured directly. These holes can readily be closed with a welding torch if it is decided that the equipment is safe for continued operation.

It would not be practical and not all companies could afford to maintain as elaborate an inspection organization as does this petroleum refinery. But even in the smallest plant the basic principle of this inspection service can be applied to equipment where corrosion, high temperatures and pressures, or the possible danger of fire and explosion render operations hazardous to life, property or even the uninterrupted flow of profits. Frequent inspection is an inexpensive substitute for many of the liabilities of severe service.

Coal Conference At Carnegie Tech

SIGNIFICANT to the growing importance of bituminous coal as a raw material for chemical manufacture is the forthcoming International Conference on Bituminous Coal at Carnegie Institute of Technology in Pittsburgh, Nov. 15-19. No more timely service could have been rendered to the group of industries interested in coal processing than that President Baker of Carnegie Tech has provided through the medium of this conference. Coal and its by-products are assuming in the eyes of industry the importance generally perceived in them by science and engineering. As a basic raw material coal has its incidence on fertilizers, dyes, explosives, motor fuels, solvents, pharmaceutical and photographic chemicals. In the variety and intricacy of its ramifications through industry, coal and its products are approached in importance only by cellulose. The Pittsburgh conference will be notable for its international character. Bergius and Fischer of Germany, Patart of France, Lander and Lessing of England, Parr, McIntire and Fieldner of the United States and other eminent figures in the technology of coal will appear personally on the program. The problems of coal production will not be discussed. Modern methods of processing will hold the entire stage.

International Chemists Tour American Industries

THE FALL convention season was enlivened this year by the annual meeting in Washington of the International Union of Pure and Applied Chemistry. Sessions in the national capital were followed by a ten-day industrial tour that took foreign and American delegates to Wilmington, Pittsburgh, Akron, Detroit, Niagara Falls, Rochester and Schenectady for a brief glimpse of American industry. From a scientific point of view the proceedings were not notable, for the Union functions principally through committees dealing with international standards and uniformity and does not attempt to stage the elaborate scientific sessions that

characterized the international congress held before the war. But in its social aspects, in its promotion of international good will, in its creation of international understanding despite the barrier of diverse languages, in its opportunity for international amity and accord the convention was a conspicuous success. Social foundations were laid for future scientific and commercial intercourse. Fifty-three foreign delegates from fourteen countries mingled with each other and with many times their number of American scientists in the course of the meeting and tour. The beneficent influence of such associations must be profound in its effect on international peace, in fostering a spirit of sympathy and toleration, and in promoting universal prosperity and higher standards of living. Germany will doubtless join the Union in the near future; and after two more annual meetings in Europe the tri-ennial congresses probably will be resumed. The International Union will then have served a noble purpose in restoring worldwide solidarity in the chemical profession.

Electrochemists Discuss Severe Service Problems

ROUNDING out twenty-five years of commendable service in electrochemistry and electrometallurgy, the American Electrochemical Society devoted its fiftieth meeting, held in Washington this month, to new problems incidental to our rapid industrial expansion. It is now an old story that "Niagara Falls made Detroit possible"; that abrasives and ferro-alloys produced by electrothermic processes contributed primarily to the cheap and rapid production of the automobile as well as to its sturdiness and serviceability. But if the proceedings of the recent Washington meeting are a criterion, new industrial problems are being brought to the door of the electrochemist in the hope of a solution that will make other industries more profitable and efficient. The approaching era of high-pressure chemical technology is demanding new materials of construction and new processes of fabrication in which electrometallurgy must play a part. New refractories are needed for each of the following requirements: high heat conductivity, high thermal insulation, resistance to corrosion of slags and gases, and for melting pure metals. The ever present problem of overcoming losses due to corrosion calls for new metals and alloys for special purposes. All in all the opportunities for electrochemical and electrometallurgical development are still great despite the service already rendered. The Society is to be congratulated on its continued lively existence as evidenced by the recent symposium under the able direction of Dr. H. W. Gillett. A report of the proceedings is included in this issue.

Alcohol Trade Association Has Auspicious Beginning

ONE of the incidents of the month served as a happy reminder of the spirit of friendliness and generosity that is pervading American industry. Following a meeting in New York of the recently organized Industrial Alcohol Manufacturers Association, the Kentucky Alcohol Corporation invited the association to visit its new model distillery at Deepwater, N. J. Competitors, representatives of the Government and

of the technical press were guests on that occasion; and no host was ever more cordial to his visitors, more solicitous for their comfort and convenience or more generous with technical information. The day was devoted to good fellowship.

There is no longer any novelty in the idea that members of an industry should know their competitors. Several hundred trade associations in the United States testify to the acceptance of this principle by American industry. But the evidences of human friendliness in trade relations are still few enough to make the action of the Kentucky Alcohol Corporation noteworthy. The industrial alcohol industry is confronted with numerous problems, some of which can be solved best by co-operative effort. Competing products are on the horizon, uses are shifting. Concerted as well as individual alertness, research and investigation are desirable for future growth and protection. These objectives will be reached more quickly if friendly personal relations exist among individual members of the industry. If the visit to Deepwater can be taken as an outward evidence of inward purpose, the new association has made an auspicious beginning.

A Victory and An Opportunity

DESPITE the great confidence with which the chemical industry awaited the final outcome of the Government's suit against the Chemical Foundation, a very general feeling of relief is evident as a result of the favorable decision reached by the United States Supreme Court on October 12. This outcome of the long and useless litigation by which the Government, through charges of fraud and corruption, had attempted to set aside the sale of German-owned chemical patents marks the end of the period of uncertainty that always accompanies interpretation of legal technicalities.

This confirmation, by our highest tribunal, of the famous decision reached three years ago by Judge Hugh M. Morris of the district court in Wilmington, Delaware, is a personal vindication of the motives of the men who conceived this bold means of establishing and fortifying the position of our organic chemical industry. Likewise it is a victory for chemical industry—the more so because the general good that the Foundation has already accomplished can now be greatly extended.

It is not likely that the constructive program which the Chemical Foundation has outlined for itself will be dependent solely on the life of the patents it now holds. Its broad charter of service for "the advancement of chemical and allied science and industry in the United States" will permit it to improve its patents and to acquire others. In fact it is only in this way that the Foundation may be perpetuated for otherwise its income would be depleted with the expiration of its present patents. The energies that have been devoted to the legal conflict and the license money withheld pending the confirmation of Foundation ownership, will now be available for constructive work in the interest of chemical industry.

Chem. & Met. extends its congratulations to the officers, directors and stockholders of the Chemical Foundation for their significant victory. May the legal conquest so decisively won be the first measure of the future success of the Foundation in its broad program of service to the chemical industries.

Materials for Extreme Conditions in the Electrochemical Industries

Severe Service Symposium Proves Attractive Feature of Washington Meeting of American Electrochemical Society

Editorial Staff Report

IN SPITE of the many conflicting technical and scientific meetings scheduled for the first two weeks of October, an unexpectedly large number of electrochemists attended the convention of the American Electrochemical Society in Washington October 7 to 9. Many valuable technical contributions were presented and the discussions were of unusually high merit. The most attractive feature of the program was the timely symposium on "Materials for Extreme Conditions" planned and directed in an able manner by its chairman, Dr. H. W. Gillett of the Bureau of Standards.

Dr. H. J. French, senior metallurgist of the Bureau of Standards, presented a carefully prepared survey of the present status of the various "Metals to Resist Corrosion or High Temperatures." Extracts from this paper appear elsewhere in this issue. The increasing importance of the ferro-alloys, in particular the high-chromium steels, was emphasized by the author and the many participating in the discussion. Norman B. Pilling, metallurgist of the International Nickel Co., pointed out that the alloy: 20 per cent Cr, 10 per cent Ni, balance Fe, not mentioned by Doctor French had found wide application in Germany. William M. Corse gave an account of tests carried out by Sir Robert Hadfield in England this summer. An automobile fitted with bright metal parts made of Stabrite (8 per cent Ni, 18 per cent Cr, bal. Fe) was operated through rain and storm. After the car was dry it was only necessary to dust the parts with a cloth to restore the original bright luster. Stabrite costs about 6 to 12 times as much as ordinary steel and the non-ferrous alloy manufacturers are planning to meet its competition by supplying chromium-plated nickel-silver parts. As regards the resistance of alloys to acetic acid, Henry Howard of the Grasselli Chemical Co. cautioned against reporting resistance or non-resistance to attack of a certain metal or alloy without specifically mentioning the concentration of the acid used. Further discussion included reference to the aluminum-silicon alloys by J. D. Edwards of the Aluminum Company of America, Colin G. Fink of Columbia, T. G. Leek of the West Virginia Pulp & Paper Co., and others. The alloy "Alpax" containing about 13 per cent of silicon, balance aluminum, is being used in but small amounts in this country but in ever increasing quantities abroad.

Vincent T. Malcolm, metallurgical engineer of the Chapman Valve Mfg. Co., referred to the needs of the oil refiner. What is wanted is a metal or alloy that will withstand high temperatures, high pressures and an atmosphere containing H_2S . With such a metal available much greater yields in the refinery would follow. There would be a saving as high as 25 per cent. Stainless steel has not proved satisfactory.

Stanley M. Norwood, in his paper on the welding of high-chromium alloys showed how his company, the Union Carbide and Carbon Co., overcame the many difficulties inherent in the welding of alloys containing more than 10 per cent chromium. The most serious problems are those of brittleness in the weld and in the base metal adjacent to the weld; a brittleness that cannot be relieved even by heat treatment in alloys containing 20 per cent or more of chromium. These obstacles have been overcome by the addition of 8 per cent nickel to high-chromium alloys. The objection of diminished corrosion resistance to sulphur products, generally accompanying the addition of nickel, has been removed by an addition of 2 per cent silicon. The presence of manganese in percentages equal to the silicon improves the welding characteristics of the alloy.

In discussion John A. Seede, electrical engineer of the General Electric Co., reported that the high-chromium alloys could be welded with the atomic hydrogen arc without much difficulty. Dr. John A. Mathews, vice-president and metallurgist of the Crucible Steel Co., took exception to Norwood's statement that the addition of nickel to chromium steels lowered the resistance to sulphur compounds. He stated that the plain ferro-nickels, say 30 per cent Ni, are quite resistant to sulphuric acid and moderately resistant to HCl, in which respect they differ from the straight chromium alloys.

"Materials of Construction for Nitrogen Fixation" was the title of the paper by Dr. J. G. Thompson of the Fixed Nitrogen Research Laboratory which is abstracted elsewhere in this issue.

REFRACTORIES FOR EXTREME CONDITIONS

Dr. M. L. Hartmann, director of the research laboratory of the Carborundum Co., with O. B. Westmont, research chemist of that laboratory, undertook an elaborate study of the thermal insulation of electric furnaces. The thermal conductivities of fused alumina, fused fireclay and a high temperature insulating refractory were given in addition to the published data on silicon carbide (carborundum) and silica. The temperatures, heat losses and heat capacities of thirteen types of electric furnace linings were tabulated, with the inside surface temperatures assumed to be 1,600, 1,400 and 1,200 deg. C. The object of the paper was to suggest possibilities of energy conservation in electric furnaces by properly designed composite walls.

The question of water-cooled electric furnace linings was introduced by Henry Howard and in answer to the inquiry as to the thermal losses of such furnaces, John B. Glaze, research engineer of the Norton Co., stated that in their experience the losses are comparatively small. Clarence E. Sims, Bureau of Mines, reported

that he had found no great advantage in water cooling over air cooling the refractory lining. It is well to bear in mind that the properties of insulating materials are very often reversed at high temperatures as compared to the properties at low temperatures.

F. A. J. Fitzgerald of Niagara Falls reported the use of recrystallized silicon carbide for the septum of electric furnaces developed for the firing of porcelain at high temperatures. His paper is abstracted elsewhere in this issue. Leon O. Hart of the Driver Harris Co., used a carborundum resistor and found a drop of 600 deg. C. after two weeks' operation.

Linings for electric brass furnaces were discussed by Max Unger in his paper on "Refractories for Induction Furnaces." Magnesium oxide proved to be the one refractory more nearly fulfilling the conditions than any other. Proper grading of the magnesium oxide is very important. Pitch was selected as the best bonding material. For continuous operation on steel and a slag analyzing 20 to 25 per cent silica, the magnesium oxide lining will last through 600 heats. Dr. E. F. Northrup of the Ajax Electrothermic Corporation pointed out that the importance of the refractory disappeared when the melting operation was carried out very rapidly. Using a No. 60 crucible in a small 150-kw. induction furnace the entire melting and casting operation was completed in about a half hour. The secret of success is the "terrific speed of melting."

Frank S. Weiser of the Scovill Mfg. Co., Waterbury, laid before the meeting the following unsolved problems of the brass industry: (1) A thermocouple that will not alloy with brass. (2) Molds that will give perfect brass castings and have a good life and low cost. (3) Stirring rod for brass. (4) A satisfactory method of continuous pickling of brass, a tank lining and other fittings that will resist 6 per cent hot sulphuric acid saturated with copper and zinc salts, such lining and fittings, furthermore, to resist abrasion. Doctor Gillett reported that a satisfactory lining for brass is made up of a mixture of water-ground and air-ground fired magnesite. The durability of this lining, with its uniform outside glaze, was demonstrated to the members during a visit to the Bureau of Standards after the symposium.

A new refractory, a thorium zirconate, was described and reported upon by George E. Merritt of the Bureau of Standards in his paper on the "Thermal Expansion of Some Fused Oxides Used as Refractories." Doctor Northrup was most enthusiastic about this new refractory and felt that it was the beginning of a new era. The zirconate Mr. Merritt reported was made of equimolecular proportions of ThO_2 and ZrO_2 . The coefficient of expansion at 900 deg. C. was almost zero. Its fusing point is probably 3,000 deg. C.

The concluding paper of the symposium was that of W. W. Winship, of the Thermal Syndicate, Ltd., who outlined the advantages of vitreous silica and vitreous quartz for unusual requirements. A paper on this subject by the same author is published in this issue.

Under the chairmanship of Dr. William Blum, president of the Society, an interesting technical session was held on Friday on the electrodeposition of zinc, copper, cadmium and iron. The papers of this symposium and their discussion will be reviewed in detail in a subsequent issue of this magazine.

Dr. C. J. Thatcher presided at the Saturday morning session, which was devoted to papers on organic electro-

chemistry. Introducing the subject he referred briefly to the electrolytic manufacture of benzidine at Milano, Italy and at Bâle, Switzerland.

"Electrochemical Chlorination and Bromination of Benzene" was the first of three contributions by Prof. Alexander Lowy and his students at the University of Pittsburgh. This first paper showed that it is possible to chlorinate benzene by stirring it with concentrated hydrochloric acid and electrolyzing. The main product is chlorobenzene. This investigation showed that the amount of chlorobenzene was the same in both the electrolytic and the non-electrolytic experiments. In the case of bromination, the electrolytic and non-electrolytic experiments produced bromobenzene in about equal amounts, and this was the only product observed. This reaction is an electrochemical one.

Sir Richard Threlfall of Birmingham, England, in complimenting the research workers suggested the use of Pt in place of carbon as electrode material. Using the silver-lead anode proposed by Doctor Fink, Sir Richard felt that a film of silver chloride would be obtained which might interfere with the reaction at the anode. But Doctor Fink stated that an oxide outer film and not a chloride, was formed. Dr. W. C. Moore of the U. S. Industrial Alcohol Co., urged upon the investigators the use of solvents other than water. Phenyl hydrazine, absolute alcohol and other solvents gave promise of producing compounds not possible with aqueous electrolytes.

ORGANIC ELECTROCHEMICAL REDUCTION

"The Electrochemical Reduction of Indigo" invited a lively discussion. Doctor Blum of the Bureau of Standards felt that we could bring about cathodic reductions purely electronically without the intervention of hydrogen. Sir Richard Threlfall emphasized the importance of proper and sufficient stirring of the electrolyte. Professor Lowy and J. Nevyas had made a quantitative study of the current efficiency of the electrochemical reduction in finely divided suspension in solutions of sodium hydroxide with a mercury cathode. The current efficiency (a) decreases with increasing current density, (b) increases with increasing temperature, and (c) increases with increasing concentration of alkali.

In studying the electrolytic oxidation of *p*-bromotoluene and *o*-nitrotoluene, Professor Lowy and John F. Conn subjected these compounds to electrolytic oxidation in dilute nitric acid solution. The first was converted to *p*-bromobenzoic acid with excellent yields. The favorable conditions are: (a) an electrolyte of 20 per cent nitric acid; (b) platinum electrode; (c) vigorous stirring; (d) a current density of 0.50 amp. per sq.dm.; and (e) temperature of 100 deg. C. *Ortho*-nitrotoluene was converted to *o*-nitrobenzoic acid in low yields. A resinous material, oxalic acid and carbon dioxide were the other products formed on oxidation. No solvents were used.

The closing paper of the session was that of L. U. Spence and P. B. Cochran of the Westinghouse company on the utilization of ozone in the drying of insulating varnishes. The time required for the drying of varnishes by this method is approximately 50 per cent of the time required for baking in air. The results of tests show that the quality of the insulation produced by baking in ozonized air under the proper conditions is equally as good, and for some applications better, than the films produced by the slower air-baking process.



Conveying Synthetic Gypsum

Calcium sulphate is obtained as a byproduct in a large Eastern chemical plant. This plant desired to use the material in the manufacture of building materials, but found themselves confronted with a difficult problem. There was sufficient space at the point where the sulphate was produced to accommodate calcining kettles, but the manufacture of the finished product must be done elsewhere.

Calcined gypsum is a difficult substance to move unless it is bagged. It was obviously uneconomical to bag the material at the calciners, move it across the plant, and then empty it out of the bags again at the building material plant.

The solution hit upon, which has proved to be highly successful, is the use of a pneumatic conveying system for handling this material. This system is shown in the illustrations on this page. Fig. 1 shows the hopper into which the calcined sulphate is discharged from kettles. Under this hopper is the intake of the pneumatic conveying system with the pipe line leading from it. In Figs. 2, 3 and 4 the path of this pipe line across the plant is shown, and in Fig. 5 is the end of the pipe line where it discharges into the storage bin at the building material plant.



High Pressures and Temperatures

WE ARE ON THE THRESHOLD of an era of high-pressure technology. In a large measure the recent growth of nitrogen fixation has been both the cause and the effect of this development. It has brought with it the successful application, on an ever increasing scale, of temperatures and pressures which but a few years ago were beyond the possibilities of engineering design and construction. It has pointed the way to even greater developments in the technology of high pressures. The commercial synthesis of methanol from carbon monoxide and hydrogen is a step in this direction. Synthol and the hydrogenation of naphthalene and other hydrocarbons are similar industrial achievements of the last few years. Others, now on the horizon, open up a virtually unexplored field in chemical technology—one of major interest to the chemical engineer since successful achievement in this field lies primarily in the solution of engineering problems.

But had there not been a simultaneous development and improvement of materials of construction, chemical technology would doubtless have already reached its limitations. Peculiar importance attaches, therefore, to the first of the discussions that follow—which, in the words of its author, is an attempt “to bring together in condensed form widely scattered information on the important metals used industrially to resist high temperatures and corrosion, and to point out the direction of developments within this field.”

It is possible in this section to discuss but a very few of the industrial applications that involve severe service problems for equipment and materials of construction. Among these are nitrogen fixation, petroleum refining—particularly the cracking process with its use of high pressures and temperatures—hydraulic pressing, and important developments in the field of refractories and heat-resisting materials.

Metals for Service at High Temperatures

Characteristics and Typical Applications of Principal Heat-Resisting Materials of Construction Used Industrially

By H. J. French

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THE SELECTION of metals for high temperature service presents problems similar to but varying in detail from those for corrosion resistance at atmospheric or slightly elevated temperatures, and ordinarily must include consideration of stability. However, physical properties, such as hardness, ability to withstand stresses and resistance to erosion, are generally of greater importance and frequently constitute the controlling factor in any choice.

Many metals are used at temperatures well above atmospheric, as, for example, brasses and bronzes which find application in low pressure steam service or aluminum alloys which are used in pistons in internal combustion engines. However, in this discussion, attention will be given mainly to those which are suited for more severe requirements,

and which come within the following groups: (1) cast irons, malleable iron and ordinary carbon and low alloy-content structural steels; (2) chromium-iron and nickel-chromium-iron alloys (often with other elements); (3) nickel and nickel-copper alloys, and (4) nickel-chromium alloys. Typical compositions and notes concerning some of their outstanding applications or properties at high temperatures are given in Table I.

CAST IRONS, MALLEABLE IRON AND ORDINARY STEELS

Cast irons and ordinary steels are widely used in steam service, furnace construction, ingot molds and stools, containers for metal baths and many other purposes, and their high temperature properties have received considerable attention.

Cast irons, as is well known, are subject to permanent changes in volume upon repeated heating to high temperatures, and as a result their field of usefulness has been

somewhat restricted. This effect, commonly called “growth,” is dependent upon composition and the time-temperature changes to which the iron is subjected. Gray irons generally grow while white irons are said to shrink, but with prolonged heating of white irons containing more than about 3 per cent of carbon there is a tendency to deposit temper carbon and the metal will then tend to grow. According to Rugan and Carpenter (*J. Iron and Steel Inst.* 1909, part 2, p. 29; 1911, part 1, p. 196), an alloy of practically constant volume under repeated heating to temperatures as high as 1,650 deg. F. (900 deg. C.) is a white iron containing about 3 per cent carbon and only small amounts of other elements and in particular less than about 0.2 or 0.3 per cent silicon. This is recommended for annealing ovens, rolls, fire bars, steam valves and turbine casings, and is stated to be quite tough.

In steam service cast iron is recommended for a total temperature of 450 deg. F. (230 deg. C.) when the pressure does not exceed about 25 lb. gage, and for 100 deg. F. (38 deg. C.) when the gage pressure is not greater than about 75 lb. Malleable irons and semi-steels are recommended for temperatures up to about 500 deg. F. (260 deg. C.) when the pressure does

Extracts from a paper presented before the American Electrochemical Society in Washington, D. C., October 7, 8 and 9, 1926, and published by permission of the Director of the Bureau of Standards, Department of Commerce.

not exceed 200 lb. gage; at higher temperatures or pressures cast or forged steels are recommended.

The compositions and treatments of steels may be varied to meet specific requirements at temperatures well above 500 deg. F. (260 deg. C.), but these alloys can not be expected to stand up when continuously subjected to fairly high stresses at temperatures exceeding about 1,200 deg. F. (650 deg. C.). At moderately high temperatures, say up to about 1,000 deg. F. (540 deg. C.), improved mechanical properties may be obtained in small sections by heat treatment, but care

should be exercised that the tempering subsequent to hardening is carried out at temperatures well above those encountered in service, as otherwise the metal may not be in a stable condition.

The temperatures of marked "weakening" of ordinary carbon steels may be raised by additions of special elements, such as chromium, but for severe service at very high temperatures, for example, above about 1,500 deg. F. (815 deg. C.), it seems necessary to seek alloys in which iron plays a secondary rôle, instead of forming the largest part of the product. However, its

elimination is not necessary and from some viewpoints is undesirable.

An important application of cast steels is in valves and fittings for power plants and oil refineries. These are usually made from about 0.3 per cent carbon steel or medium-carbon low nickel-chromium steels. The latter type is claimed to have superior load-carrying ability around 800 to 1,000 deg. F. (415 to 540 deg. C.).

SPECIAL STEELS

The possibilities of meeting special requirements at high temperatures with the special steels, through the use of different combinations of alloying elements, may be illustrated by a few applications and the results of recent research.

According to Aitchison (*Engineering*, 108 p. 799, 1919), inlet and exhaust valves of internal combustion engines may, for working temperatures up to about 1,100 deg. F. (595 deg. C.), be made of ordinary 3 per cent nickel-steel, but for more severe service, often encountered in airplane engines, in which the working temperatures are between about 1,100 and 1,400 deg. F. (595 and 760 C.), a high-chromium steel containing about 0.65 per cent carbon and 10 per cent chromium is recommended. Working temperatures above about 1,400 deg. F. (760 deg. C.) require the use of such steels as the high-tungsten-chromium type containing about 0.65 per cent carbon, 16 per cent tungsten and 3.75 per cent chromium. However, conditions are sometimes encountered in which none of these is entirely satisfactory. In tests reported by Johnson and Christiansen (*Proc. A.S.T.M.*, 24, part 2, 1924) the chromium-tungsten steels scaled excessively, while those high in chromium (about 13 per cent or less) and to a smaller degree the conventional low-carbon types, containing both chromium and silicon, lost their hardness at the high temperatures of operation with resultant galling of that portion of the valve stem subjected to the exhaust flame. Similar difficulties were encountered with the steels containing 20 to 25 per cent nickel and 5 to 15 per cent chromium. The best of the group studied, although not wholly satisfactory, contained relatively high carbon (in the neighborhood of 1.2 per cent), 12 per cent chromium, 3.2 per cent cobalt and 0.7 per cent molybdenum.

Aside from the value of the dif-

Table I—Some Metals for Service at High Temperatures

Type Chemical Composition, per Cent										
C		Mn	P	S	Si	Ni	Cr	Cu	Other Elements	Fe
Combined	Total									Remarks
3	3	0.25	0.12 to 0.20	0.07 to 0.12	0.7					† For annealing boxes, pots and pans.
0.7	3.4	0.7	0.20 to 0.50	0.06 to 0.10	1.5					† For ingot molds and stools.
0.35 to 0.60	3.0 to 3.50	0.9 to 1.2	<0.35	<0.10	1.6 to 2.0					† "Semi-steel."
	0.25									† For steam service, in castings, wrought products, etc.
	0.3					2.5	0.7			† For castings, steam service valves and fittings.
	0.65					1.7	0.7		Mo 0.7	† For hot-working dies, moderate temperatures.
	0.9						3.7			† For hot-working dies, more severe service.
	0.2						2.5		W 8.5	† For hot-working dies, more severe service.
	0.5						4		W 10	† For hot-working dies, more severe service.
	0.4				3.5		8.25			† For automotive engine valves.
	0.4				3.3		3.25			† For automotive engine valves.
	0.65						10			† For internal combustion engine valves, operating at fairly high temperatures.
	0.65						3.75		W 16	† For internal combustion valves, operating at very high temperatures.
	1.2						12		Mo 0.7 Co 3.2	† For internal combustion engine valves, operating at very high temperatures.
	<0.12						13			† For temperatures up to about 1,475° F. (800° C.). Has good resistance to scaling.
	0.3						13			† Better resistance to scaling.
	0.3						20			† Fine resistance to scaling; not very high load-carrying ability.
	*						25			† Fine resistance to scaling; not very high load-carrying ability.
	0.3						30			† For spark points; steam service; electrical heating units (moderate service).
	0.3	1				30				† Very good resistance to scaling.
	1.8					5	20			† Very good resistance to scaling.
	*				3.0	24	27			† Good load-carrying ability and resistance to scaling at highest temperatures, in comparison with most metals listed above.
	*				<3.5	30 to 40	15 to 20	<1.25		† Good load-carrying ability and resistance to scaling at highest temperatures, in comparison with most metals listed above.
	*					60 to 65	10 to 20			† For high temperature electrical service.
						85	15			† For high temperature electrical service.
						80	20			† For steam service, such as valve seats. The 5 per cent Mn-nickel for spark points.
	†					94 to 99				† For steam service, such as valve seats; turbine construction.
	1	2				67		28		2
						60		26	Sn 11	1.5
	1.5					35	1 to 5			5

*Varied to meet specific requirements.

† Balance, including impurities and small amounts of elements usually present in commercial alloys.

‡ C + Si = 0.25 to 5.0.

Note: For detailed data relating to the physical properties of some of the alloys listed above, refer to the symposium on Effect of Temperature on the Properties of Metals, Proceedings A. S. T. M., 24, pt. 2 (1924).

ferent alloys for valves, these tests bring out an important feature, likewise confirmed in other work, that the high-tungsten-chromium steels retain a relatively high degree of hardness at high temperatures, say up to about 1,400 deg. F. (760 deg. C.), as well as good load carrying ability, but have rather unsatisfactory resistance to scaling. The low-carbon high-chromium steels are superior in resistance to scaling, but soften more at the highest temperatures. These characteristics have, of course, an important bearing upon many other applications of metals at high temperatures.

The construction of steam and gas turbines presents problems involving resistance to erosion and the ability to withstand various types of stresses, acting simultaneously. Combined with the desire for low-cost materials, ease of fabrication and reproducibility, these constitute severe high temperature service requirements. Monel metal, the high-nickel and the high-chromium steels have all found applications in this field, but the latter appear to be better adapted to the present and more severe requirements.

Resistance to sulphur gases at high temperatures is sometimes an important industrial requirement. Ordinary steels and irons and alloys high in nickel are readily attacked by the gases encountered in the combustion of high sulphur fuels, sulphide ore roasting furnaces and the cracking of high-sulphur oils, and for such conditions other alloys are required. Aluminum shows good resistance to hydrogen sulphide, even at high temperatures, but is very soft and has little or no load-carrying ability at temperatures in the neighborhood of and above about 480 deg. F. (250 deg. C.). The alloys which now appear most promising are the high chromium steels or irons containing about 20 per cent or more of chromium.

The term "heat resisting alloys" has most often been applied to the nickel-chromium and nickel-chromium-iron alloys, and seems originally to have been associated with a high degree of resistance to oxidation at very high temperatures. However, in its broadest sense, as it is now coming to be used, it refers to those metals which are primarily suited for service at very high temperatures, whether the requirements include resistance to oxidation or other forms of stability. Accord-

ingly, other metals are included within the meaning of the term, and there is an overlapping of this group with the special steels already described, such, for example, as those containing high chromium or relatively high chromium and nickel.

While the alloys here to be discussed cover a wide range in compositions, the most important of the current industrial types are fairly well standardized, and come within the limits shown in Table I.

A good example of the successful application of some of the nickel-chromium-iron alloys is found in the production of ammonia. Early experiences in France with the Claude process developed that carbon and the high-tungsten-chromium steels were unsuited for the high temperature-high pressure containers, which exploded after short periods in experimental installations. On the other hand, an alloy containing about 60 per cent nickel, 12 per cent chromium, balance iron plus impurities, stood up well in both cast and forged conditions.

SEVERE TESTS IN HABER PROCESS

Extended experiments carried out in this country with reference to the Haber process and reported by Vanick (*Proceedings, A.S.T.M.*, 24 part 2, 1924) indicate a high degree of resistance on the part of some of such alloys for synthesizing and decomposing mixtures of ammonia. Nickel, Monel metal, nickel-iron and other alloys failed by intergranular fissuring and attendant loss in strength and ductility, whereas an alloy containing about 16 per cent each of nickel and chromium and 3.25 per cent silicon was only slightly affected after a 6-months' exposure.

In many types of service, resistance to oxidation and the ability to withstand abrasion or stresses, or the need for high hardness at very high temperatures are individually or collectively major requirements. As examples there may be cited the moving parts in heating furnaces for the continuous or semi-continuous heat treatment of steels, enameling racks and trays used in the ceramic industries, furnace bottoms, supports for oil stills, annealing pots and boxes, pyrometer tubes, etc.

From the standpoint of resistance to oxidation at the highest temperatures, the nickel-chromium and nickel-chromium-iron alloys show quite general superiority in compari-

son with the ordinary irons and steels, nickel, nickel-copper alloys and the 13 per cent-chromium steels. Their superiority in comparison with the iron-chromium alloys containing about 20 per cent or more of chromium is not so marked, and little if any better than those containing 25 per cent or more of this element; however, they have much better load-carrying ability.

The nickel-chromium-iron alloys, as a group, also show superiority in load-carrying ability at high temperatures. It should be noted that the high-chromium steels and irons do not have the high load-carrying ability with which they are sometimes credited, though at intermediate temperatures—below about 800 deg. F. (425 deg. C.)—those which respond to heat treatment have an advantage over the nickel-chromium-iron alloys and other metals, which do not harden appreciably by thermal treatments.

The proportions of nickel, chromium and iron present in these alloys are, of course, important in determining physical as well as chemical properties at high temperatures, but it should be kept in mind that other elements may exert a marked influence upon high temperature "strength" and rigidity. Just as in the case of steels, the addition of appreciable proportions of hardening elements, such as carbon, tungsten, etc., improves their high temperature hardness and load-carrying ability, but at the same time reduces malleability. There are, therefore, greater possibilities in castings than in wrought metals for the most severe mechanical requirements. No one alloy is best for all purposes, but in the group listed in Table I will be found those which serve well for a variety of applications. Some, as indicated in the tabulated data, have properties which make them valuable in electrical heating units, thermocouples, as containers for or in contact with molten metals, etc. For example, containers for molten lead baths used in heat treatment, may, under ordinary operating conditions at temperatures below about 1,300 deg. F. (700 deg. C.), be made of cast iron, or pressed steels. For higher temperatures, the high-chromium-iron alloys, sometimes containing silicon, or the nickel-chromium-iron alloys are recommended, their economical application, of course, being dependent upon the exact conditions of service.

Nitrogen Fixation Involves Combination of High Pressures and Temperatures

Operating Difficulties Overcome by Developing Proper Materials of Construction to Withstand Unusual Conditions

By J. G. Thompson

Fixed Nitrogen Research Laboratory, Washington, D. C.

COMPRESSION, storage and delivery of gases and gaseous mixtures under high pressure have presented many problems of an engineering nature. In the synthesis of ammonia, the general trend has been continually toward higher and higher pressures, so that tests which originally were made at a few atmospheres pressure were soon extended to 100, 200 and 300 atmospheres. At present most of the tests on catalysts, at this laboratory are done at 100 or 200 atmospheres, while research investigations are carried on at higher pressures. Considerable work has been done at 1,000 atmospheres, and occasionally 1,500 atmospheres has been used.

The compression system briefly is as follows: A four-stage, 4,000-pound (1,815 kg.) compressor receives gas at atmospheric pressure from ordinary water-sealed gas holders, and delivers it to a high-pressure storage system, which consists of a number of steel cylinders, each of 1.6 cu.ft. (0.045 cu.m.) capacity. Tests at 100 or 200 atmospheres are made on gas drawn directly from this storage system. For higher pressures, gas from this first storage system is delivered to a cylinder which is connected with a hydraulic pump. The cylinder full of gas is further compressed by the hydraulic pump and is discharged to a second high-pressure storage system of steel cylinders. In this way, pressures as high as 1,500 atmospheres, 22,500 pounds per square inch (1,582 kg. per sq.cm.) have been maintained for experimental work.

Even at the lower pressure of 100 or 200 atmospheres numerous difficulties were encountered in attempts to produce gas-tight systems. Small leaks are much more serious than in low-pressure or hydraulic work, owing to the fire and explosion hazard, as well as to the value of the purified gases. The difficulties

in designing and maintaining a gas-tight system obviously increase as the pressure is increased.

For laboratory tests, the high-pressure tubing used to transport the compressed gas is seamless drawn steel, 0.0625 in. (1.59 mm.) inside diameter by 0.1875 in. (4.76 mm.) outside diameter. Connection with valves, tees, etc. (see figure), is made by means of a cone and gland assembly. This consists of a steel tube 0.25 in. (6.35 mm.) outside diameter, terminating in a cone 0.375 in. (9.5 mm.) diameter and 59 deg. angle. Over the tube is fitted a threaded steel gland. This assembly is attached to the supply line tubing by means of a steel sleeve and silver solder. The cone and gland is fitted into the valve or tee by means of a standard gland and cone seat having a 60-deg. angle. The bearing surface is thus reduced to a single line at the extreme inner edge of the cone tip. The torque required on the bushing nut to tighten the joint is very small, and may be applied by a small hand wrench.

Connections made by means of a steel sleeve and silver soldering the joints have proved entirely satis-

factory on the 0.1875 in. (4.76 mm.) tubing used for experimental work. None of these joints has ever failed in service, provided it was originally tight. For larger tubing, with thicker walls, tight contact between the tube and a steel sleeve is obtained by the use of a steel compression cone and gland as shown in the figure.

COMBINING HEAT AND PRESSURE

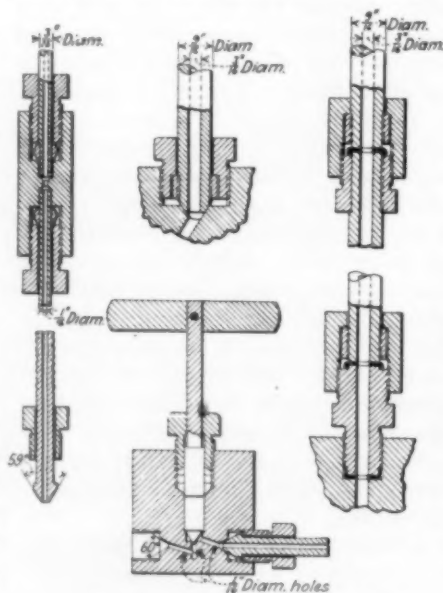
The combination of temperatures of 450 to 500 deg. C. with pressures of 100 atmospheres or more, on systems containing hydrogen, nitrogen and ammonia gases furnishes severe conditions for structural materials. Bombs containing catalysts for the synthesis of ammonia failed rapidly, and the bombs used in "cracking" ammonia, when pure gas containing exactly three hydrogen to one nitrogen was desired, failed even more rapidly.

Failure of these metals was due to intergranular fissuring. Only those samples exposed to "cracking" ammonia were corroded in the ordinary sense, that is, with visible attack of the surface accompanied by disintegration or the formation of chemical compounds. Nearly all of the materials suffered deterioration as measured by loss in mechanical properties, such as tensile strength and ductility. Of the samples tested, iron-base alloys containing nickel, chromium or aluminum seem to offer the most resistance to deterioration.

It appears from tests that the primary requirement of a steel to resist the action of nitrogen and hydrogen, in the synthesis of ammonia at 100 atmospheres and 500 deg. C., is a chromium content of at least 2 per cent, combined with a carbon content of not more than one-seventh or one-eighth the amount of chromium present. No element tested, except chromium, has been found to impart satisfactory resistance to corrosion under these conditions. Other alloying elements, such as nickel, tungsten, or vanadium, may be added to improve the physical properties of the steel, but these additional elements cannot replace chromium, although in some cases they appear to reinforce the corrosion resistance created by the presence of chromium. Further tests are in progress, mainly on a series of chromium-tungsten steels.

SPECIAL PROCESS REQUIREMENTS

Urea Process—The synthesis of urea from ammonia and carbon diox-



High-Pressure Tubing and Valves for Handling Gases at Pressures as High as 22,500 lb. per sq.in.

Extracts from a paper presented before the American Electrochemical Society at Washington, D. C., October 7, 8 and 9, 1926.

ide presents some unusual corrosion and structural problems. In this process, liquid ammonia and liquid CO₂ pass slowly up through an autoclave, where they react, at 150 deg. C. and under a pressure of 100 atmospheres, to form urea and water.

The products of the reaction are discharged periodically from the top of the autoclave through a pop-valve, which must function perfectly for the successful operation of the process. The requirement that the valve must reseal over a pressure of 100 atmospheres necessitates almost perfect resistance to corrosion by both valve and valve seat. Experiments have shown that most of the common metals are badly attacked under the conditions existing in the autoclave. A few metals and alloys have been found which appear to be satisfactorily resistant to corrosion, but some of these lack the necessary strength and hardness. For instance, a lead-antimony alloy is a satisfactory protective lining for the steel autoclave, but is obviously unsuitable for valve construction. At present, tests are under way on a chrome-plated machine steel valve and valve seat. Preliminary tests indicate that this combination possesses the desired properties, but final service tests have not been completed as yet.

Ammonia Oxidation—The oxidation of ammonia, the primary product of most of the processes of nitrogen fixation, to form nitric acid is one of the projects under investigation at the laboratory. Ammonia gas in the presence of a catalyst at elevated temperatures reacts with oxygen to form NO and H₂O. The nitrous oxide reacts spontaneously with excess oxygen to form N₂O₄, which can be absorbed in water to form dilute nitric acid.

Such a process requires materials resistant to the corrosive action of gaseous mixtures of oxides of nitrogen, nitric acid and water at temperatures up to 200 deg. C., and of nitric acid throughout the entire range of concentration from faintly acidified water to concentrated nitric acid or to anhydrous N₂O₄. In addition to their resistance to corrosion, these metals or materials must be suitable for fabrication into pipes, condenser tubing, valves, pumps and compressors.

Cyanide Process—The fixation of nitrogen as sodium cyanide has been studied at the laboratory. In this

process nitrogen reacts with a mixture of sodium carbonate, iron and carbon at about 1,050 deg. C., to form sodium cyanide. The reaction is carried out in a rotating metal cylinder externally heated by gas flames. Considerable difficulty was encountered in finding a metal to re-

sist the oxidizing action of the impinging flames and the corrosive action of the hot carbonate-cyanide charge inside the cylinder. The early cylinders were very short-lived, but the modern cylinders, of special nickel alloy, operate satisfactorily.

High Temperature Oxidation in Roasting Furnace

Heat-Resisting Alloy Proves Practical for Rabble Arms, Blades and Other Metal Parts

IN BURNING pyrites for sulphuric acid manufacture and in the roasting of blende to produce zinc oxide the metal parts of the roasting furnace must withstand oxidation at high temperatures and resist both the corrosive action of the sulphur gases and the mechanical abrasion of the heated ore. Temperatures of 950 to 1,050 deg. C. are not uncommon in the upper hearths of such a furnace. With the proper design of the furnace the excess heat involved in the early stages of the reaction can be used to supply higher temperatures required to drive off the last portion of the sulphur, thus eliminating the necessity for burning auxiliary fuel.

In the Wedge multiple hearth furnace illustrated in Fig. 1 this heat is conserved by making a recuperator of the arm. These arms are connected in series and the air passing through them (the primary purpose of which is to cool the arms) absorbs an appreciable amount of heat. Instead of exhausting this to

the atmosphere, this air is returned to one of the lower hearths of the furnace to boost the temperature at this point. In this way no great amount of excess air or foreign combustion gases are introduced into the furnace to interfere with acid making if the sulphur gases are used for that purpose.

To withstand the severe operating conditions imposed on the arms, rabbles and rabble holders it is desirable to use a heat-resisting metal. At these elevated temperatures, cast iron does not possess sufficient strength to carry, in addition to its own weight, several hundred pounds of rabbles and holders. Fahrite CS, a cast alloy high in chromium, has been successfully employed for the metal parts of the Wedge furnace. It is unaffected by oxidation or corrosion under these conditions and is many times stronger and resistant to abrasion than either iron or steel. One furnace operator has reported comparative tests in which such a furnace was equipped with rabble blades of eight different alloys, all of which were placed into service simultaneously. The number of service hours ranged from 100 for a special cast alloy steel to over 5,000 for cast Fahrite.

The same alloy is also of value for other parts of the furnace exposed to hot destructive gases and mechanical abrasion. Such an application is to be found in the ring casting that rides the rotating central shaft of the furnace, projecting downward into the bed of roasting ore to prevent the ore from bypassing between the stationary hearths and the central shaft. Such castings when made of ordinary gray iron must be replaced frequently and as they are rather inaccessible, each replacement means a shutdown of the furnace.

The preceding information has been furnished by E. L. Malone of Rice and Malone, engineers for the Fahrite division of the Ohio Steel Foundry Co., and J. R. Barrett, manager of the Wedge furnace department of the Bethlehem Foundry and Machine Co.

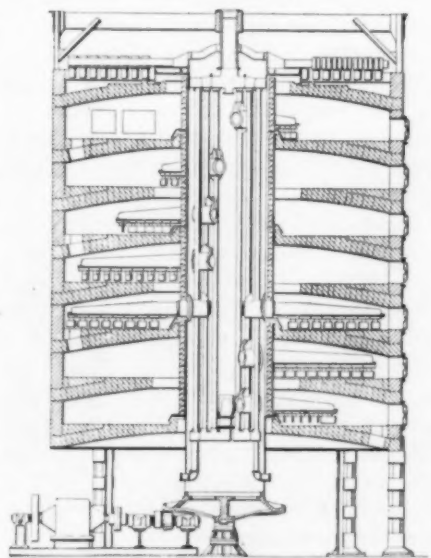


Fig. 1—Multiple Hearth Roasting Furnace with Rabble Arms of High Chromium Alloy

Building a Valve for a Pressure of Three and a Third Tons

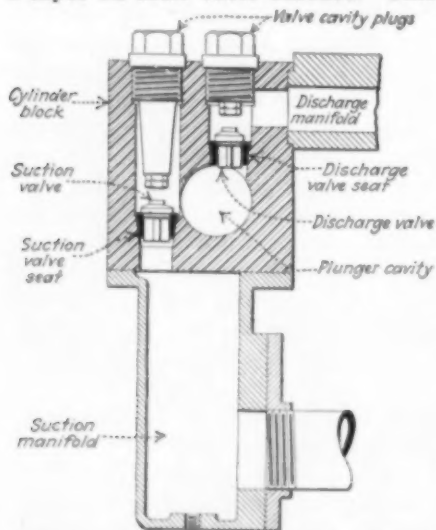
Acute Problem in Designing Valves and Seats Arose as Hydraulic Equipment Was Converted to Higher Operating Pressures

By D. H. W. Felch

Mechanical Engineer, The Richardson Co., Melrose Park, Ill.

NOT THE LEAST difficult among the problems of operating and maintaining high-pressure hydraulic pumps is in the valves and seats. This problem became more acute recently in converting such pumps to a higher operating range than that for which they were designed. The existing hydraulic equipment in the plant of the Richardson Co. to which extensions were being made operated at 2,000 lb. line pressure, and it was necessary to convert to this pressure three newly purchased pumps designed to operate at 1,500 lb. working pressure.

Some attention was given to valve and seat design at the time of converting the pumps, but it was determined to operate them under observation before going to the considerable expense of redesign and replacement. The accompanying drawing illustrates the valve construction and operation by a transverse section through the water end of the pump. There are twelve suction and twelve discharge valves to each pump. The cylinder blocks are solid steel forgings drilled for all plunger and valve cavities. The valve seats are cylindrical in form bored straight on their inner contour, and turned to a taper on their outer surface. This



Transverse Section Through the Water End of Hydraulic Pump Illustrating the Valve Construction and Operation

taper is $\frac{1}{8}$ in. per in. and engages with a similar taper in the cylinder block which supports the valve seat in place. The valves as originally furnished were of the barrel type and were cast of a corrosion-resisting, high-tensile strength nickel alloy. The seats of one of the three pumps were of a good grade of cast gun bronze often named hydraulic bronze when used in this field. The seats of the second pump were of the same nickel alloy as the valves. The seats of the third pump were of hardened tool steel. These are separately enumerated since the third pump was valved by its original manufacturer while the other two were valved by another hydraulic machinery manufacturer at different times. The three, therefore, represent various practices as to proper materials for high-pressure hydraulic-pump valves and seats.

HIGH PRESSURE CAUSES VALVE SEIZURE

Observations taken from time to time after the pumps were put into service showed that the nickel alloy and gun-bronze seats were gradually being pushed through the cylinder blocks by pressure on top of them. This pressure was about $3\frac{1}{2}$ tons per valve. As the seats were pushed or extruded through the cylinder block the metal in the seats displaced by the taper in the cylinder block closed in and seized the valves, in some instances, preventing them from functioning. It was felt that there might come a point in the movement or extrusion of the seats through the cylinder block where this movement might cease altogether so that it was determined to turn down the barrels of the valves to compensate for the closing up of the seats. This expedient worked well for a time, but eventually certain valves and seats on one of the pumps blew through the cavities below the taper in the cylinder block causing a shut down and some repairs.

While this extrusion movement of the softer metal seats on two of the pumps was taking place, the hard-

ened tool steel seats in the third pump were observed to remain fixed in place. However, water for this hydraulic system is highly corrosive to tool steel so that regrinding of the seats at too frequent intervals was necessary with eventual deep pitting of the seats and resultant replacement easily forecast. The softer non-ferrous seats and valves did not require this frequent regrinding however, apparently being impervious to corrosive attack by the water used.

NON-CORRODABLE AND NON-DUCTILE

The problem was well defined now—to obtain seats of non-corrodable metal at the same time non-ductile or rigid so that extrusion through the valve cavities would be resisted. Some little experience had been gained in this same problem in operating valves for hydraulic presses with the final result that the company had standardized on a simple valve of its own design, cast from a copper-aluminum-iron alloy of unusual density and great tensile strength, making it ideal for use in high-pressure valves. Engineers from the Hills-McCanna Co., manufacturers of this alloy, were called into consultation and their No. 45 alloy valves were determined upon for the pumps with a newly developed No. 50 alloy for the seats. This latter metal is a copper-nickel-iron-chromium alloy of high tensile strength and great hardness indicating non-ductility. As a matter of further insurance against the extrusion movement of the seats, it was determined to increase the section of their walls. This made the inner passage through the seats less in area since it was not practical to bore the cylinder blocks to permit increasing the outside diameter of the seats. Calculations were made showing that it was permissible to increase the velocity of the water through the seats. As a matter of opinion of design the valves were changed from barrel to four-wing type.

The first set of No. 50 alloy seats were made to gage both on their exterior as well as interior contour. Gaging on the exterior was felt to be necessary to insure as near as possible a perfect fit with the existing taper in the cylinder blocks. The plug gage used in making the interior bore of the seats was also to be used as a gage after installation of the seats to determine whether or not the seats tended to extrude and

thereby close up under use. After 200 hours of continuous operation immediately following installation of the first set it was found that the seats had closed up beyond the limit of the plug gage indicating that some settling or extrusion of the seats had occurred. It was felt however that this first settling might be due to an adjustment of the taper of the seats to any possible irregularities in the taper of the cylinder blocks. The plug gage was ground to a point where it passed the seats, as settled, and another run of 120 hours was made after which the seats were gaged. This time it was found that there was no discernible difference in the gage fit, making it appear that no further sinking of the seats had occurred. The next inspection occurred after 400 additional hours of continuous running with no measurable closing up of seats on the gage being noticeable.

RESISTANCE TO EROSION

At each inspection both valves and seats were examined for erosion. It was found that the copper-aluminum-iron valves showed some slight pitting but no transverse scratches or deep markings due to water passage over the seat as is often the case in wire drawing of water over gun bronze seats. The copper-nickel-iron-chromium alloy seats showed no erosion, being the most remarkable metal in this respect ever observed by the writer. By way of illustration the following is indicative of the hardness and at the same time toughness of this metal. One of the valve cavity plugs was carelessly screwed down onto one of the valves which had not been entered properly in its seat with the result that the valve was considerably dented needing replacement, but the seat was uninjured, a desirable result since the valve is the least expensive and more easily replaced unit.

The valve cavity plugs previously mentioned were originally supplied of cast iron which seemed to supply enough strength in the threads for use at 1,500 lb. working pressure, but which failed at 2,000 lb. working pressure. These plugs have all been replaced by ones of similar construction but of the copper aluminum iron alloy, advantage having been taken of its tensile strength (equal to a good grade of steel) and its non-corroding quality preventing corrosive adherence to the threads of the valve cavities.

Expansion of Fused Oxides Used as Refractories

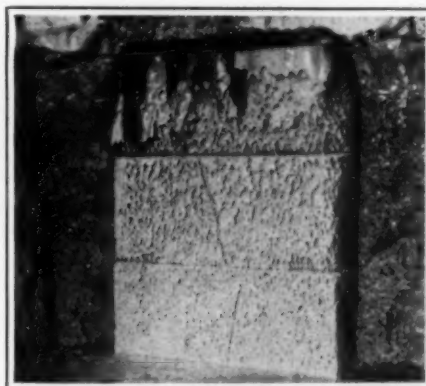
The thermal expansions of the oxides of silicon, thorium and zirconium, of a mixture of one-to-one molecular proportions of thorium and zirconia, and of the refractories made of magnesite, alumina and zirconia have been measured by George E. Merritt of the U. S. Bureau of Standards, who presented a paper before the recent meeting of A.E.S. The following table gives the average co-efficient of expansion from room temperatures to 800 deg. C. of each of the materials considered, except thorium zirconate, for which an average coefficient would be misleading.

Thermal Expansion of Some Fused Oxides Used as Refractories

Substance	Coefficient of Expansion $\times 10^6$ (25°-800° C.)
Alumina, refractory made of..	7.9
Magnesia, refractory made of..	13.4
Silica	0.5
Thorium	9.3
Zirconia, parallel to long axis of crystal	8.1
Zirconia, perpendicular to long axis of crystal	7.3
Zirconia, refractory made of..	6.6

Mullite Refractory Used in Glass Melting Tanks

The use of refractory compositions made from synthetic mullite (formerly known as sillimanite) in glass melting tanks at points where the refractory wear is most severe has been a means of greatly increasing the life of these tanks. At the Columbia Glass Co., in Los Angeles, a Durox refractory of this type made by the Vitrefrac Co. has been used in the flux line blocks. The accompanying photograph, taken after nine months of service, shows the greater resistance of this refractory.



Flux Line Blocks in Glass Melting Tank

The greater resistance of the mullite refractory (Durox) to the glass batch is shown by the fact that these blocks project four or five inches beyond the face of the clay blocks.

Recrystallized Silicon Carbide as a Refractory

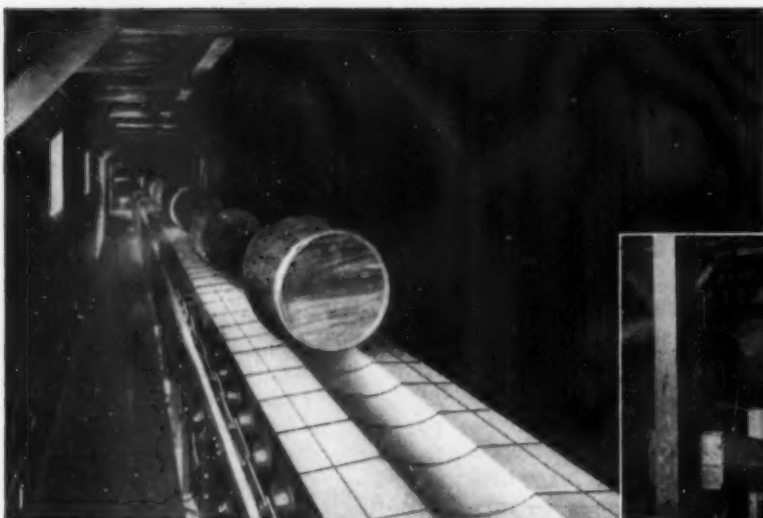
F. A. J. FitzGerald of Niagara Falls, N. Y., in a paper before the American Electrochemical Society at the Washington meeting discussed a somewhat difficult refractory problem presented in certain electric furnaces developed for the firing of porcelain at high temperatures. The resistors in these furnaces are made of graphite, and are enclosed in gas-tight resistor chambers separated from the chambers in which the porcelain is fired by a septum which forms the floor of the resistor chamber and the roof of the firing chamber, through which the heat is conducted from the resistor chamber and thence radiated to the porcelain ware.

The refractory which looked most promising for meeting the exacting specifications for the septum was recrystallized silicon carbide (U. S. patents 650,234-5). Articles of recrystallized silicon carbide are made by mixing with granular or powdered silicon carbide a temporary bonding substance, such as glue, molding into the desired form and then heating in a furnace to a temperature equal to that at which silicon carbide is formed.

Use of the furnace to heat the ware in the resistor chamber to temperatures of 1,450 deg. to 1,500 deg. C. continuously over long periods (a month to six weeks) failed to show the least sign of softening or distortion of septum tile made from recrystallized silicon carbide.

Refractories for Cement Kilns

By replacing fire-clay brick with high-alumina brick, a large mid-western cement plant reports a notable increase in life of the hot-zone linings in 4 kilns. In "Kiln No. 4" for example, 10 ft. of Arcofrax high-alumina brick was installed Aug. 27, 1925. The kiln was shut down for 31 hr. on Oct. 27, 1925; for 70 hr. on Dec. 1, 1925 and for 85 days on Feb. 1, 1926. In March, 1926, the remainder of the hot zone was lined with the high-alumina brick, and an inspection in August, 1926, showed that the entire lining, including that part installed the previous year, was still in good condition. The records of life in the other 3 kilns show similar resistance to severe conditions.



Problems in Handling Finished Goods

What are perhaps the most difficult of all handling problems are encountered when a product is finished and must be packed, stored and shipped. Such problems are almost infinite in variety, varying with the product, the type of package, the quantity handled, and the physical surroundings. For this reason there can be no set solution for such problems, but each case must be studied separately and the best possible means for accomplishing the necessary handling determined to suit the conditions.

The four pictures on this page show some successful installations of this type. In Fig. 1 is a wooden apron conveyor that proved economical for moving barrels of sugar from the point where packed to the warehouse and shipping platform.

Fig. 2 shows one way of moving bagged fertilizer from the machines to the car, the moving platform conveyor permitting the workers to close the bags as they travel.

In Fig. 3 heavy pails of white lead are moved by a portable apron conveyor directly to the car into which they are being loaded, thus saving much manual labor.

Fig. 4 shows a steel belt conveyor for handling sliced bacon from the slicing machine to the packers. The special advantage realized here from using a



steel belt lies in the fact that the grease from the bacon can be readily removed from the belt and hence sanitary conditions are more easily maintained.



Explosion Hazards

PAST records disclose a surprising total of dust explosions both within and without the chemical engineering industries. Industry owes much to the investigators, who have succeeded in reducing preventative measures to a science. One of the leaders in this field is David J. Price of the Bureau of Chemistry. Plant engineers should find Mr. Price's article instructive, and we urge a reading of Mr. Reid's discussion also. In many industries, safe lighting as well as adequate lighting, is an absolute essential.

Another example of the interrelation of efficiency and safety is the storage of petroleum and its distillates. The Wiggins roof appears to be a marked advance over ordinary tank construction. Of especial interest is the ingenious seal between the floating roof and the tank wall, which prevents most of the evaporation loss and, at the same time, keeps out air effectually. Repeated tests of extreme severity have demonstrated the fire-proofness of construction which eliminates "breathing" by the device of a practical floating roof.

Some Chemical and Engineering Aspects of Dust Explosions

Plant Location and Design, Fineness of Dust, Relative Humidity and Dust Removal Have Important Bearing on Origin and Extent of Explosions

By David J. Price

Engineer in Charge of Development Work,
Bureau of Chemistry, U. S. Department
of Agriculture

PLANT construction is related closely to the origin and extent of dust explosions. In a number of explosions, the value of certain types of construction, for example large window glass areas, has been well demonstrated. In the design of a chemical plant, for instance, we will find that the dust explosion hazard exists in practically all types of processes, such as transporting, energizing, reacting, separating and conditioning. In the transporting process, explosions may originate in the elevators, conveyors, loading and unloading machines, and in practically all types of material handling and conveying equipment.

In the separating process, certain causes in the operation of separators, collectors, sifters, and machines of this character may result in disastrous dust explosions. When we reach the conditioning process, we find that in grinders, crushers, rolls, and practically all types of pulverizing equipment, ignition sources can be produced which will ignite dust clouds and result in explosions. In the heating equipment of drying, reacting, and energizing processes, explosions can originate at certain times.

Fires and explosions have occurred

in driers when the temperature has been considerably below the ignition temperature of the material. The question is, what causes these fires? Does prolonged heating at comparatively low temperatures change the chemical composition of grain dust, wood dust and starch so that the resulting material has an ignition temperature lower than that of the original dust? Some work is being done on this problem by the Bureau of Chemistry at the present time, but no definite conclusions have as yet been reached.

HAZARDS OF SPRAY DRIER

The spray drier is another type of drier in which fires and explosions have occurred. It may not be more hazardous from a dust explosion standpoint than some other types of equipment, nevertheless the hazard exists and care should be exercised in selecting not only the type of drier but also its location in relation to the rest of the plant.

HOW TO STUDY A DUST EXPLOSION HAZARD

When an explosion hazard has been definitely determined in a particular process, it has been advantageous, when practical, to isolate this part of the operation. If a hazardous process can be isolated, as a rule the extent of the explosion is localized

and the damage confined to a limited area.

Certain factors contribute to the explosibility of a dust, one of the principal factors being the degree of fineness. Flame propagates rapidly through a 200-mesh cloud, and the rate of flame propagation appears to increase in proportion to the relative degree of fineness. Based on the results of recent work by Bouton and Hayner, it appears that there is a limit to this relationship of fineness to flammability. Recent experiments with two types of coal, one from the Pittsburgh bed in Pennsylvania and the other from the Pocahontas bed in West Virginia, were conducted to obtain a quantitative relationship between fineness of dust and its tendency to flare up when suspended as a cloud and ignited at some point. In reporting this work the investigators state: "The experiments gave the unexpected result that flammability does not increase indefinitely with fineness but seems to reach a maximum and then fall off, or at least remains constant, as the fineness is still further increased." (*Bulletin No. 22, Carnegie Institute of Technology, "Rate of Combustion of Coal-Dust Particles, Part 2—Effect of Particles Size Upon Pressure Increase Attending Flammation of Coal Dust,"* Bouton and Hayner). The results of these investigators indicate that the greatest pressure was developed when the particle size ranged from 10 to 25 microns in diameter.

The following theoretical considerations may be of interest:

Three possibilities—two chemical and one physical—are being considered by Bouton and Hayner in relation to this peculiar reluctance of very fine suspended dust to flame. First, it may be a property of coal dust that when pulverized the very

Extracts from paper read at Technical Sessions, Chemical Equipment and Process Engineering Exposition, Cleveland, Ohio, May 14, 1926.

fine dust is of somewhat different chemical nature than the coarser dust, because some constituents are more friable than others. Second, the process of elutriation, used in the experiments in which the dust was suspended in the air for long periods, may have caused a greater oxidation of the finer particles than of the coarser ones. Third, very fine dust may tend to agglomerate or form groups of particles, so that a cloud of this dust may actually be less completely dispersed in air than a coarser dust.

SIZE OF CEREAL DUSTS

With cereal dusts, it is doubtful whether the chemical composition of the very fine particles would differ from that of the coarser particles or whether they would oxidize as readily as coal dust of the same particle size. The third possibility, namely, that the very fine dust may agglomerate or form groups of particles, so that a cloud may be less completely dispersed in air than the coarser dust, would hold with the cereal dusts as well as with coal dusts. This work, although based entirely on two type coal dusts, indicates the necessity of further research with grain dusts and other industrial plant dusts to determine fully the relation of degree of fineness to explosibility.

The design of dust collecting systems is vitally important to this dust explosion problem. In some instances explosions have occurred in the dust collecting pipes and also in the dust collector. The successful collection of dust by mechanical equipment (in the handling by fans and pipes) bears a close relation to the explosive concentration limits. In the design of these dust collecting systems it is essential that engineers be fully acquainted with the dust explosion hazard and the conditions under which the dusts can be ignited and flame propagated.

At present the relation of relative humidity to explosion frequency is receiving much attention. It has been claimed that the explosion hazard will be reduced by an increase in the relative humidity. So far the work done on this phase of the problem has been limited. It appears, however, that it cannot be generally claimed that the increase in relative humidity will entirely eliminate the dust explosion hazard.

Laboratory tests have shown that saturated air at 25 deg. C. has about the same dampening effect on explosibility as 1 per cent carbon dioxide.

Saturated air contains a certain amount of water vapor, depending on the temperature, and this water vapor acts, of course, as an inert gas, but at ordinary temperatures the effect of this inert gas on reducing the oxygen content is small and does not approach the oxygen dilution required to prevent an explosion from propagating. Dusts which are placed in saturated air will absorb a certain amount of water, which acts as an inert material, but tests have shown that the amount of moisture thus absorbed will not prevent an explosion from propagating.

It is true that with increased humidity the possibility of the formation of static electricity may be reduced, owing to the thin film of moisture which acts as a conductor for the static electricity, thus permitting the charges to be neutralized or grounded. There are engineers who feel that much protection can be afforded by the introduction of a humidity control system and that the entire subject is a matter for further research.

MECHANISM OF DUST EXPLOSIONS

We now know that dust explosions occur in what may be termed two stages; primary and secondary. A primary explosion is usually an ignition of a small quantity of dust with localized effect. The concussion accompanying this original ignition, however, is sufficient to shake into the air any settled or collected dust, resulting in a rapid propagation of flame and in what is termed a secondary explosion. In this explosion

considerable pressure is developed and as a rule the plant is badly damaged.

The need of effective dust-removal systems for both suspended and static dust is therefore shown. By efficient dust removal the propagation of flame is prevented and the secondary explosion, as a rule, limited in extent. Progress has been made recently in the development of pneumatic cleaning systems for the removal of settled dust throughout the plant. It has been demonstrated that proper maintenance and "good housekeeping" are essential in dust explosion control.

ELIMINATING STATIC ELECTRICITY

One of the common causes of dust explosions has been the ignition of dust clouds by sparks of static electricity. In the control of explosions and fires, a wire grounding method has proved effective in connection with the operation of threshing machines and cotton gins. The main difficulty with any grounding system is that the wires may be broken, which in some cases makes a greater hazard than if the machine were not grounded. However, with good maintenance grounding is an effective method for eliminating static.

Recently, work has been done by the Bureau of Chemistry to develop several materials (patents applied for) for coating belts and similar surfaces, which produce a dry flexible surface on the belt. The results thus far indicate that the materials remove all static. The wearing qualities and effectiveness of the several

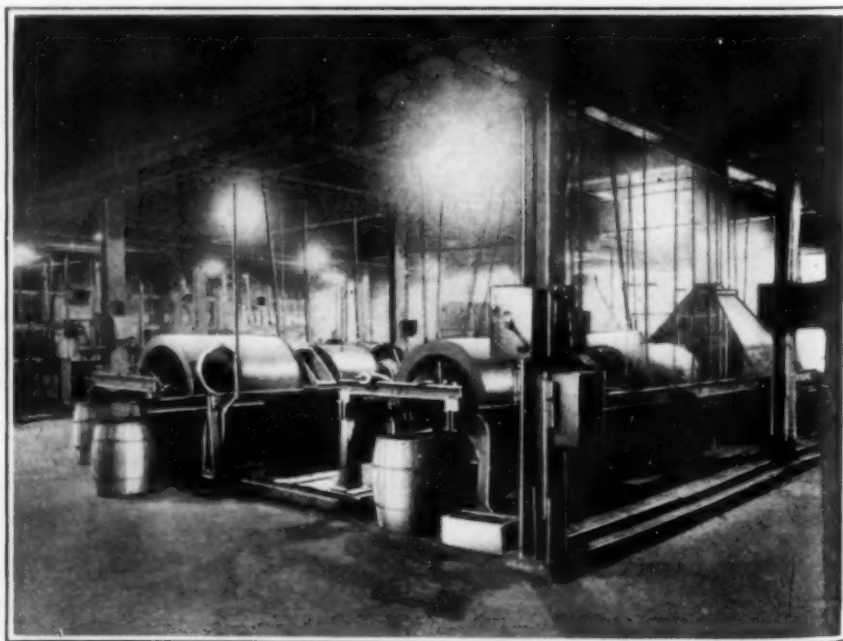


Fig. 1—Good Lighting in a Large Pickling Room

materials are being tested under actual industrial conditions. When this work is completed a final report will be made.

Safe Lighting Equipment for Dusty Industries

Both Gas-Filled and Vacuum
Lamps Should Be
Protected

By Kirk M. Reid

Engineering Department, National Lamp
Works of General Electric Co., Nela
Park, Cleveland

Editor's Note.—In the following article, Mr. Kirk M. Reid discusses a special phase of the origin of dust explosions, the possibility of ignition from incandescent lamps. Mr. Reid's discussion is intended to supplement Mr. Price's paper on "Some Chemical and Engineering Aspects of Dust Explosions."

IT HAS been said that dust explosions have been caused by the breakage of an incandescent lamp bulb. Extensive tests have been made by the National Lamp Works, in Cleveland, to determine what hazard is involved in the use of incandescent lamps in atmospheres containing explosive or inflammable dust and what precautions should be taken to eliminate such hazards.

The tests made by the Government have shown that nearly all finely-divided dust if combined with the right proportion of air, will explode or ignite when brought in contact with an open flame. It has also been demonstrated that such dusts may be exploded by static electricity, by the electric arc from a short circuit or a loose connection in a lamp socket, or by contact with the white-hot filament of either a vacuum or a gas-filled lamp. The National Lamp Works tests have proved that the hazard due to bulb breakage is not confined to the gas-filled lamps. Any vacuum lamp, except possibly the extremely low-wattage lamps, such as the 10-watt and the 15-watt, will ignite an explosive dust cloud if the bulb is broken.

A number of tests have also been made to determine the smoking and ignition temperatures of various dusts which are commonly found. These temperatures, when compared with the temperatures of different sizes of modern vacuum and gas-filled lamps, indicate that there is a reasonable margin of safety, in most cases 150 Fahrenheit degrees, or more. No trouble was experienced in making the dusts smoke and char, but they could not be made to ignite even when the dust was packed tightly around the lamp bulb. How-

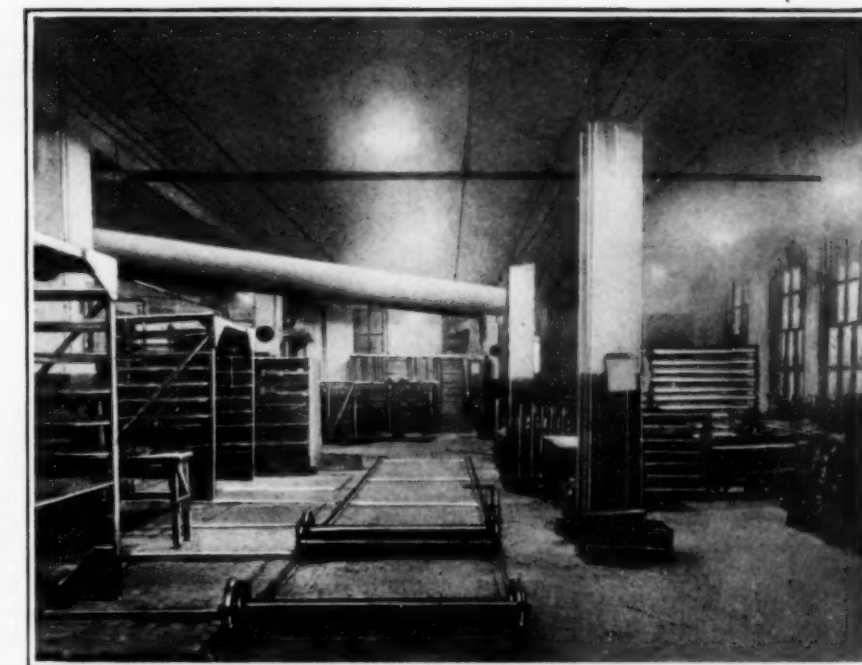


Fig. 2—Note Absence of Deep Shadows in this Japanning Room

ever, when dust accumulates on a lamp bulb and is successively heated and cooled as the lamp is turned on and off during a long period of time, the dust changes to a hard crust which may raise the temperature to the danger point. Therefore, these tests must be considered as indicative rather than conclusive.

In considering what protective measures are necessary for incandescent lamps in atmospheres of explosive dust, it does not make much difference whether the hazard arises from the accumulation of dust on the bare lamp bulb, as is commonly supposed, or whether the real danger lies in breakage of the bulb, as our tests indicate. In either case the answer is that all incandescent lamps, vacuum and gas-filled, except those of the lowest wattages, ought to be protected. Under ordinary conditions with free circulation of air around the lamp bulb, it is not likely that a fire will be started readily by vacuum lamps of small or medium size, but it is well to be on the safe side and equip them with heavy wire guards, at least. The larger vacuum lamps, such as the 100-watt, have heavier filaments which retain their heat relatively a long time and thereby constitute a hazard in case of bulb breakage. Hence, in view of present knowledge on the subject, it is clearly unsafe to use bare, unprotected vacuum lamps of the larger sizes, in atmospheres containing explosive dusts. It is not sufficient to equip these large vacuum lamps with wire guards only; unless they are

enclosed in dust-tight or vapor-proof lighting units they are definitely dangerous.

A number of manufacturers make these dust-tight and vapor-proof units, and they provide adequate protection under ordinary hazardous conditions. Where the lighting units are subject to breakage by being struck it is well to take the additional precaution of supplying heavy wire guards. Also, under extremely hazardous conditions, such as arise from the presence of highly-explosive vapor in the air, it is safer to supply the artificial lighting from sources entirely outside of the room in question.

Since safety dictates that all vacuum lamps of the larger sizes be used with dust-tight or vapor-proof units,

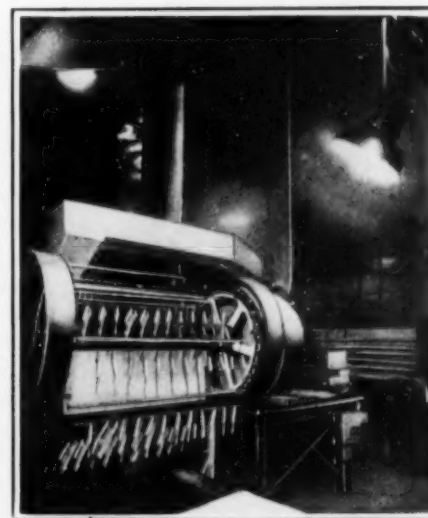


Fig. 3—Local Illumination on Duco
Spray Machine

there is no reason why industries in which combustible dusts are produced should not enjoy the benefits of the high efficiency and the low price of the regular commercial gas-filled lamps. The economy of using gas-filled lamps is evident upon considering their lower renewal cost and their greater light output for a given wattage. Unquestionably a 100-watt, or a 200-watt, gas-filled lamp which is properly protected by a dust-tight or vapor-proof globe is much safer than a bare 100-watt vacuum lamp which is unprotected. These facts point the way to better, cheaper, and safer lighting.

Preventing Fire Loss in Oil Storage

Gas-Tight Floating Roof Also Reduces Evaporation Losses, According to Tests

THE forerunner of the present Wiggins roof was developed during 1923 and on Oct. 16 of that year exhaustive fire tests were made on a roof 30 ft. in diameter and floating on gasoline. A large group of oil company officials were invited to witness the following tests: A soldering torch with 15-in. yellow flame was played against the inside of the tank shell just above the roof shoe (the most vulnerable point) for the entire circumference of the tank and no fire resulted. Flame at the mouth of one of the vents ignited the vapor mixture in the gas-tight portion of the seal, a space about $3\frac{1}{2} \times 14$ in. and 92 ft. long circumferentially. There was a rumble, flame belched from four 2-in. vents but went out instantly. Gasoline-soaked waste was ignited and dropped in one of the vents. The result was similar to when flame was directed into the vent except that the vapor ignited more slowly and the vents burned about ten seconds before going out. Gasoline was poured on the roof, ignited and burned without setting fire to the gasoline in the tank. Gasoline was poured on the horizontal part of the seal and burned for 8 min. until the oil under the seal boiled and there was no fire. Gasoline was poured over the seal so as to form a continuous gasoline contact with the gasoline in the tank. This was ignited and burned for 5 min. with but an occasional flash between the shoe and tank shell. The tests were run in rapid succession.

The principal parts of the Wiggins

roof are the float and the seal. The float is a deck of riveted or welded steel plates, kept rigid by a series of trusses and channels. This pan slopes toward the center in order that rain water be collected and carried to the outside of the tank through a flexible metal hose joined to the sump in the center. The edge of the pan is formed by a vertical rim about 22 in. high which forms a side of the gas-tight seal. The seal is formed by a 35-in. shoe which is supported from the float rim by hanger arms in such a way that the shoe is always parallel with and resting against the tank shell. A flexible gas-tight wire-woven asbestos material joins the top of the shoe and the rim of the float to make the seal gas-tight. Gas sealing is not absolutely effective on tanks. Its use here can be justified by the fact that the volume inside the gas-tight seal is so small that the breathing losses are negligible.

Where the tank shell is absolutely smooth, the shoes of a Wiggins roof maintain a practical contact with the tank shell entirely around the circumference. Should rivet heads or other projections hold the top or bottom of a shoe away from the tank shell a tall narrow slot may be opened and a small annular oil surface exposed. However, this surface is always at the bottom of a tall slot where wind currents are slow to reach and whip vapor into the atmosphere. What actually happens is that the air immediately above the surface mixes with the first vapor

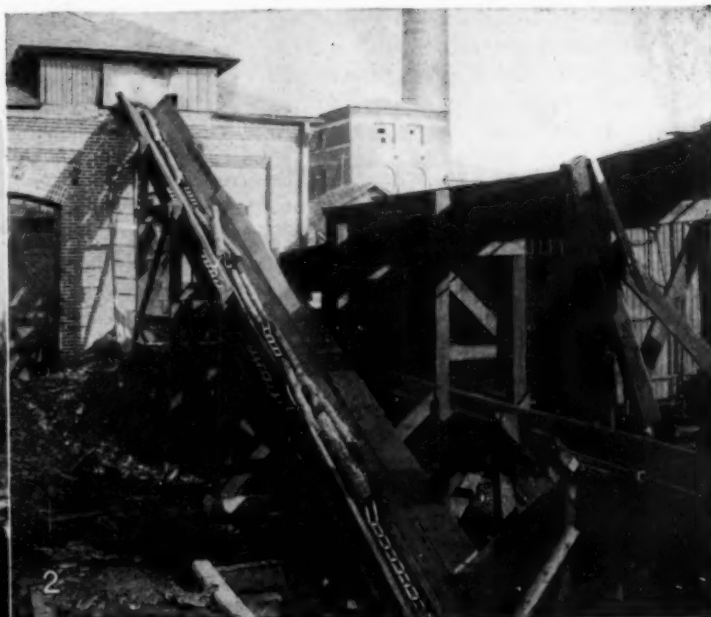
that rises forming a mixture which is heavier than air and which hangs immediately over the annular surface and protects it from further evaporation. This is known as the Wiggins principle. In order to make this principle completely effective, a secondary seal is now placed on the top of shoes on roofs covering light oils. This secondary seal consists of a loop of flexible material which extends horizontally toward the tank shell and brushes against it at all times. Wind currents are prevented from pumping the vapor out of the tall narrow slot and disturbing the vapor blanket over the tiny oil surface.

EVAPORATION TESTS FAVORABLE

Oil companies have made evaporation tests on Wiggins roofs and have obtained surprising results. One test carried on for a period of 92 days on 63 deg. A.P.I. gasoline showed that the evaporation loss from an unprotected steel tank 50 ft. in diameter and equipped with a Wiggins roof was 7.75 gal. per day. A test run simultaneously on a gas-tight completely insulated tank storing the same kind of gasoline showed a loss of 25.6 gal. per day. This latter tank was of the best possible gas-tight construction being insulated on the sides with 6 in. of hollow tile and a 4-in. air space and on top with 34 in. of insulating brick. Had the two tanks been identical in construction, a still greater difference in loss could be expected.



Rundown Tanks at Marland Refinery, Ponca City, Okla.



Reducing the Labor Needed for Handling Pulp Wood

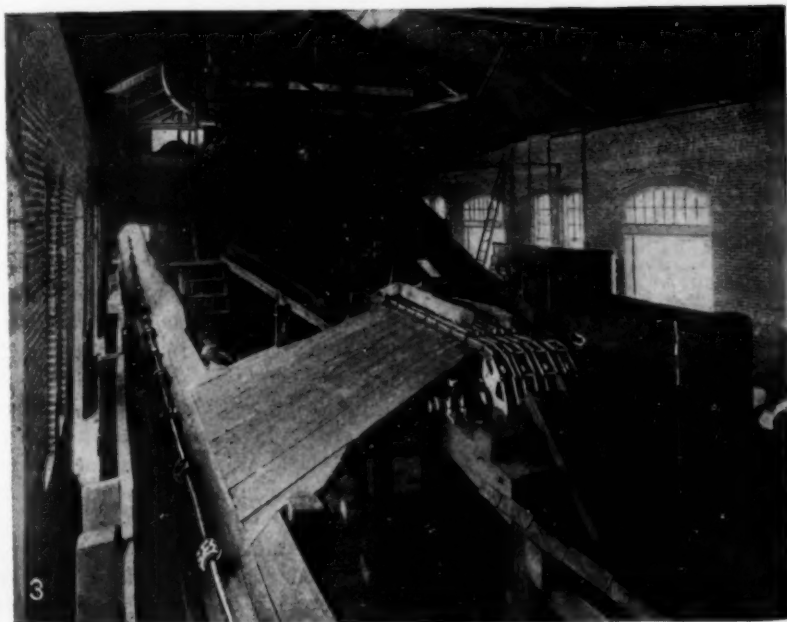


Fig. 2 shows the chain conveyor which takes logs from the lower conveyor shown in Fig. 1 and delivers them to the barking drum.

The barking drum is shown in Fig. 3, which view also shows the inspection table for barked logs. At the right, just visible beyond the barking drum, is a conveyor for taking logs to the chippers. At the left is shown the beginning of the conveyor which takes barked logs to the stock pile while the chute at the end of the table serves to reroute the imperfectly barked logs through the drum.

Fig. 4 shows the stock pile, the conveyor which feeds it and the stacking conveyor by means of which the pile is made.

Approximately the only labor needed in this installation is for unloading logs to the unbarked log conveyor, operating the inspection table, and feeding the stacker.

Many pulp plants receive the greatest part of their supply of pulp wood just when the demand for labor in other operations is at a maximum. Thus the handling of this wood by a minimum number of men is to be desired. This problem has been solved at certain mills by the installation of appropriate conveying equipment, so arranged that the wood is moved with the least expenditure of manual labor. Such an installation is shown by the illustrations on this page.

Fig. 1 shows the barked log conveyor for taking wood to the stack. Under this conveyor is a similar conveyor for taking unbarked wood to the barking drum. These conveyors operate in opposite directions, the lower toward the building shown in the background of Fig. 1, thus serving to take wood from the storage pile as well as from the cars.



Corrosion

SIX months ago, when the "Severe Service" issue of *Chem. & Met.* was but an idea, Corrosion was accorded a prominent place on the editor's planning board. The response to our call for contributions has amply justified initial plans. Although the articles have come from every source—university and industrial laboratory, equipment maker and user—those of the informative type have been preferred. Forgetting for a moment the corrosion fundamentalists (entertaining as they undoubtedly are) let us see what various chemical engineers are accomplishing:

First there is a report of the latest work on the caustic embrittlement of steel, a subject of never-ending interest and which is unfolded in a most able research by Parr and Straub. And closely related is the excellent work of Barr and Savidge on boiler corrosion. Power plant men should read these articles, too.

Next is a series of articles on the chromium irons and steels, a class of materials that is certain to have unusually wide acceptance in the chemical engineering indus-

tries. The papers by Nelson, MacQuigg and Thompson are written from different viewpoints, thus increasing their value as a group.

Non-ferrous alloys have not been forgotten. Of particular interest are the articles by Bassett and McKay. The many applications of the copper and nickel alloys should not be overlooked.

Selection of metals in centrifugal machine design has led to the fine work done by Clark and by Flowers, whose articles are presented. Petroleum refining has severe service problems of such magnitude and variety that it seemed to deserve the special consideration that it receives in this issue.

Pure iron, about which there have been conflicting laboratory reports, nevertheless has proved superior to ordinary iron and steel in numerous plant applications, examples of which are cited.

Recent developments in concrete protection and in rubber-lined equipment are of broad interest, as these are possible alternative materials of construction.

Caustic Embrittlement of Steel

Study of Its Cause and Prevention in Boilers Reveals Valuable Data for Other Chemical Engineering Applications

By S. W. Parr and F. G. Straub

Engineering Experiment Station, University of Illinois, Urbana, Illinois

FAILURE of fabricated metal used in processes where caustic solutions were involved, as in the manufacture or use of sodium hydroxide, first gave rise to the term "caustic embrittlement." It soon became evident, however, that the brittleness and cracking which developed in steam boilers using certain types of well water, either treated or untreated, bore a relation to this embrittling action of caustic solutions. This connection was definitely established early in the investigations of the Engineering Experiment Station of the University of Illinois, and Bulletin 94, "The Embrittling Action of Sodium Hydroxide on Soft Steel," issued January 1, 1917, was concerned with that subject. Further investigation carried on continuously for the past ten years has now been summarized in the recent Bulletin 155, of which the present paper is a brief editorial abstract.

The first step in the investigation was to develop some reliable means of recognizing cases of embrittlement and differentiating them

from corrosion or fatigue phenomena resulting from similar or related conditions. Corrosion cracks such as are shown in Fig. 1, however, follow lines of stress and since the usual type of corrosion in boilers is checked or inhibited by the presence of hydroxyl ions, such cracks are unlikely to occur with alkaline waters. Fatigue cracks have a cross granular character and are readily identified. Embrittlement cracks (see Figs. 2, 3 and 4), without

exception, follow grain boundaries.

The characteristics of these cracks may be summarized as follows:

(a) They do not follow what is generally considered the line of maximum stress. (b) They start on what is termed the dry side of the plate. (c) They run, in general, from one rivet hole to another, though they often run past each other, leaving islands of plate. (d) They are irregular in direction. (e) They never extend into the body of the plate beyond the lap of the seam. (f) There is no elongation of the plate. (g) Where extreme action has occurred rivet heads crack off or are easily dislodged by a slight blow of the hammer.

A summary of conditions relating to the location of cracks in the boiler may be given as follows: (a) The

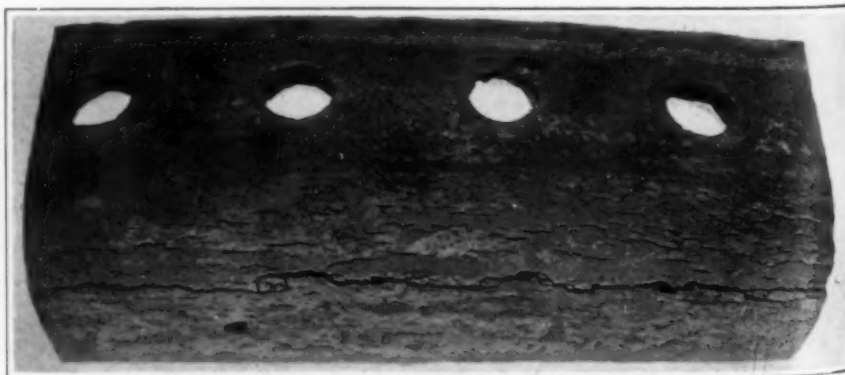


Fig. 1—Typical Corrosion Cracking on a Locomotive Flue Sheet

It will be observed that the direction of cracks follows lines of stress without regard to grain areas, that is, proceeding across grains and disregarding grain boundaries.

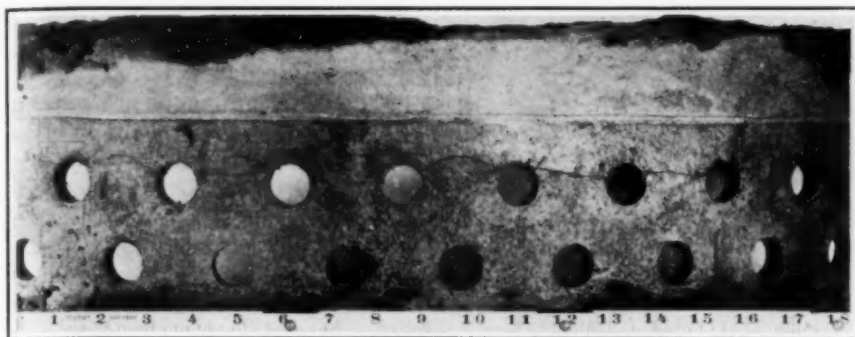


Fig. 2—Cracked Plate from an Embrittled Boiler at Waco, Texas
A distinctive characteristic of embrittlement cracks is that without exception they follow grain boundaries. In general, they run from one rivet hole to another.

cracks always occur below the practical water level. (b) They occur in seams under tension. (c) They are found at places where the highest localized stresses might be as-

the boiler, develop a caustic condition with the sodium hydroxide in material excess over the sodium sulphate.

Observation has likewise shown

Table I—Chemical Analysis of Plates from Embrittled Boilers

Location of Boiler	Carbon, per Cent	Manganese, per Cent	Phosphorus, per Cent	Sulphur, per Cent
Bloomington, Ill.	0.17	0.26	0.015	0.046
Hartland, Ill.	0.22	0.39	0.017	0.024
Champaign, Ill.	0.20	0.50	0.005	0.024
Los Angeles, Calif.	0.22	0.54	0.013	0.036
Houston, Texas.	0.26	0.34	0.014	0.025
Railway.	0.14	0.37	0.018	0.018

Table II—Analysis in Grains per U. S. Gallon of Well Waters Which Have Been Used in Embrittled Boilers

	Bloomington, Ill.	Urbana, and Champaign, Ill.	DeKalb, Ill.	McHenry County, Ill.	Waukegan, Ill.	Paxton, Ill.	Sycamore, Ill.	Los Angeles, Calif.	Dallas, Texas	Denver, Colo.	Houston, Texas
Calcium Carbonate.....	9.27	9.75	8.23	6.27	5.55	9.97	9.22	3.55	1.47	0.60	2.58
Magnesium Carbonate.....	6.82	6.34	4.72	5.18	2.99	6.64	6.26	0.38	1.01	0.26	0.00
Sodium Carbonate.....	3.21	4.52	3.93	3.12	8.82	3.96	1.99	7.71	21.70	5.96	7.1
Sodium Sulphate.....	0.00	0.10	0.08	0.00	0.83	2.36	0.16	5.72	11.92	1.49	0.0
Sodium Chloride.....	3.85	0.47	0.10	0.39	0.54	0.25	0.24	5.10	4.21	0.70	12.1
Iron Oxide and Aluminum Oxide..	0.12	0.10	0.07	0.53	0.09	0.03	0.17	...	...	0.05	0.0
Silica.....	0.58	0.82	0.40	0.23	0.31	1.82	1.18	0.95	2.51	0.63	...
Total solids.....	26.35	23.17	17.92	16.03	20.04	27.80	19.45	...	48.50	9.69	...

sumed to occur. (d) The cracks occur in plates having practically perfect chemical composition and physical properties, as well as in plates of inferior make.

Table I gives the chemical analyses of boiler plate in which a few typical cases of embrittlement have occurred and Table II shows the characteristics of the boiler waters used in such cases.

It will always be observed that:

(a) Sodium carbonate is the one substance which is always present in the feed water. (b) Sulphate hardness is usually absent or of a low ratio with respect to the sodium carbonate present. Sodium sulphate is similarly lower in amount than the sodium carbonate. (c) Boilers encountering this trouble use waters having the characteristics noted under (a) and (b), and as a consequence of chemical reaction within

that there are certain regional areas in the United States, principally in the Middle and South West where embrittlement is more evident than in others. Cases that can be traced to water treatment are comparatively few, although always a possibility unless there is knowledge of how to avoid the difficulty. The type of boiler seems to be without effect as far as the tendency toward embrittlement is concerned. Nor is there any apparent grounds for the claim that faulty composition of iron, such as the presence of dirt and impurities, is responsible for embrittlement.

In order to duplicate the conditions known to exist in actual boiler operation, a test apparatus was devised in which strips of steel could be maintained under tensile strength in a container filled with a solution of the composition being tested. (The reader is referred to Bulletin 155 or to the authors' paper presented before the A.S.T.M. in June, 1926, for details of this apparatus.) Individual tests were continued for a month or more, provided fracture did not occur earlier.

Briefly summarizing the results of tests with this apparatus, it was found that the NaOH solution must have a concentration of about 35 per cent by weight (350 g. per liter), and at the same time the stress in the metal must be above the yield-point, to produce rupture in less than a month. Neither strip stressed to 33,000 lb. per sq.in. in a 400-g. solution, nor one stressed to 47,000 lb. per sq.in. in a 200-g. solution broke

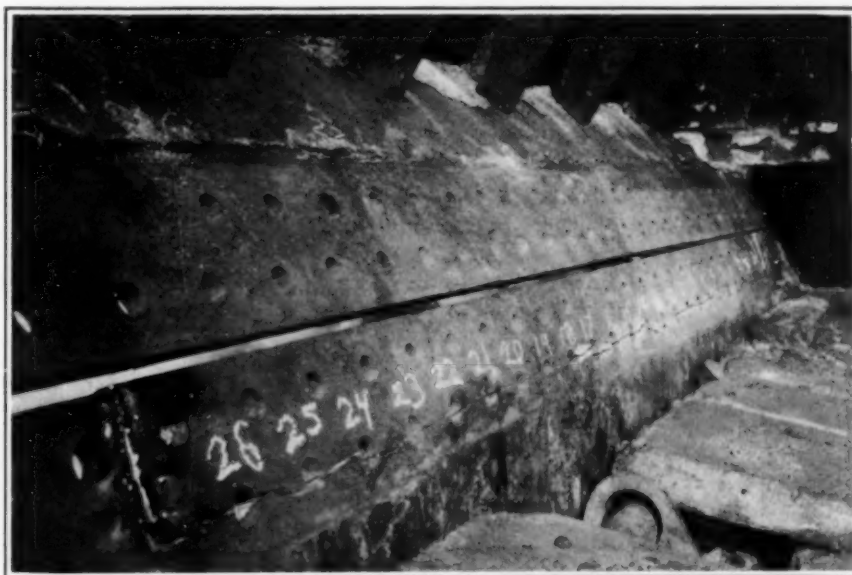


Fig. 3—Outside of an Embrittled Drum from Champaign, Ill., Cracked for 26 Rivets
This boiler, condemned after only 9 years of service, operated under conditions practically identical with those at the Illinois power plant, where Professor Parr's sulphate treatment method was used. The latter boilers are still operating and are reported in perfect condition.

(in a 16-day test). Sodium carbonate and sodium sulphate did not bring about rupture, even at stresses approximating 50,000 lb. per sq.in. and in 500-g. concentration. When these salts were present together with an injurious amount of sodium hydroxide, they tended to prevent embrittlement. When the ratio of either sodium carbonate or sodium sulphate to sodium hydroxide was above two, the rupture did not occur even though the NaOH concentration was above 400 g.

Much lower alkali concentrations than 35 per cent have been found in boilers that were destroyed by embrittlement, but it is believed that the boiler water penetrates under rivet heads and between the laps of the plate at the seams where it is highly concentrated. In fact there is the possibility that the actual concentration in the vicinity of the seam does sometimes reach a value of 350,000 parts per million. The rivet heads shown in Fig. 5 give striking evidence of the high concentrations existing in such confined spaces.

The importance of the sulphate-carbonate ratio in preventing embrittlement has been studied in the University of Illinois power plant over a period of ten years. This plant had been experiencing embrittlement troubles for some time, and, when three new drums had to be replaced in 1925 after only five years of service, the following system of water treatment was inaugurated:

The sulphate-carbonate ratio of the feed water is maintained at two. This is done by neutralizing about 70 per cent of the sodium carbonate alkalinity with sulphuric acid. The water is treated in two 40,000-gal. settling tanks. About 110 lb. of lime is added to each tank and, after sufficient agitation and settling, the required amount of acid.

Analyses are made of each tank after lime treatment and again after the acid is added to determine total



Fig. 4—The Crack Under the Head of this Rivet is Typical of Caustic Embrittlement

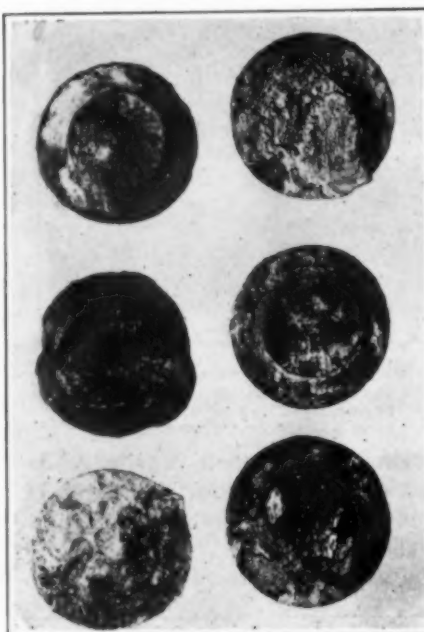


Fig. 5—Rivet Heads Removed from Champaign Boiler

These heads snapped off with a light hammer blow and show white salt incrustations in the old cracks, indicative of the high concentrations in such confined spots

alkalinity. Daily analyses are also made of the water in each boiler for causticity and total alkalinity.

After ten years of operation on this treatment the boilers were given a thorough inspection during February, 1926. Test rivets were removed and a close inspection made for signs of leaking or cracks around the rivet holes. The drums were in perfect condition. The rivets were redriven and the boilers are in operation.

On the other hand a nearby power plant in Champaign, Ill., had boilers go into service in 1916 using the same water as the University of Illinois but without the sulphate treatment, and in 1925 considerable trouble was experienced due to embrittlement (See Fig. 3.). These plants, operating for nine and ten years within 20 lb. of the same steam pressure and upon the same type of water, one acid treated and the other not, serve as a long-time experiment with results that are strictly in accord with the laboratory indications.

PREVENTION OF EMBRITTLEMENT

The results of the experimental work on the prevention or inhibition of embrittlement indicates that it can be stopped, but at present these experiments are not complete enough to cite final ratios and concentrations of the chemicals involved. The data collected from plant operation point out that the maintaining of certain ratios of these chemicals will prevent this trouble.

The removal of stresses during fabrication is not to be considered in a commercial installation, and if it were possible it could not readily be applied to the many plants already in operation. The practice of inside calking in drums will, if it can entirely prevent seepage into the seams, tend to retard the occurrence of this type of distress.

The removal of the source of the sodium hydroxide by changing the supply water would be the most effective means, but in some instances this is not possible and in others would lead to the use of waters which produce other boiler complications.

The removal of a large percentage of the sodium carbonate with the building up of a sodium sulphate-sodium carbonate ratio by the use of either sulphuric acid, or aluminum, or magnesium sulphates all have their disadvantages. The acid treatment is not to be recommended unless installed under the advice and supervision of an expert in such matters and operated under supervision of a chemist or an engineer who understands all the possibilities of danger in its use. The aluminum and magnesium sulphate treatment is very effective when used in con-



Fig. 6—Embrittled Blow-off Flange
The difficulty observed here may be accentuated by the vibratory effect produced by the blowing off process

nection with settling tanks and filters which remove the possibility of scale-forming ingredients in the boiler. These two chemicals are as dangerous, if used in excess, as acid and should be employed only after a thorough checking of the amounts necessary by a chemist who understands the reactions involved.

Summary of Conclusions.—The general conclusions to be drawn from the results obtained in the investigation may be summarized:

(a) Embrittlement in boiler plate

is caused by the combined action of stress and chemical attack. The stresses are inherent in the construction and in the operation of the boiler, while the chemical attack is caused by sodium hydroxide in the boiler water.

(b) Certain methods of water treatment tend to convert some safe waters into the characteristic type of water which produces embrittlement.

(c) The presence of sodium sulphate in the feed water and undecomposed sodium carbonate in the boiler water tends to retard the embrittling effect of carbonate waters, and if these are present in proper proportions they will stop it entirely.

(d) Methods for introducing sulphates in boiler waters have been worked out to the point of practical application.

Boiler Corrosion and Possible Combative Measures

Effect of Strained Metal, Scale-Forming Constituents, Dissolved Oxygen and Causticity with Special Reference to Locomotive Practice

By William M. Barr and Robert W. Savidge

Union Pacific System, Omaha, Nebraska

STEEL sheets for boilers and fireboxes have been well standardized and it does not appear that any of the higher-priced alloys can economically be substituted for them. Our concern therefore is with the working of the metal. Firebox sheets are flanged cold and should be properly annealed to relieve the strain set up in the bent portion. If the annealing is not properly done, these strains are points of attack.

Fig. 1 shows a flue-sheet knuckle which was in service 4 years in bad water territory. Note that while there is some corrosion on the portions of the sheet below the first row of tubes, no cracks appear except along the knuckle and extending down as far as the top of the first row of tubes. While the bad water has contributed largely to this corrosion and cracking, the original cause of this severe condition is the result of treatment of the metal when the flue sheet was formed.

It has already been stated that the bending of sheets in forming the firebox has its influence on corrosion. The breathing of the boiler from expansion and contraction incident to heating and cooling also sets up strains in the firebox sheets where rigid staybolts are attached and at the point where the flues enter the sheets. Scale at these points also has its effect on corrosion. Where the staybolt enters the sheet the scale builds up to a greater depth than on the plane surface.

After this scale accumulates, the

water is kept from contact with the steel, and as a result of this insulation, the high temperature on the firebox side soon overheats the metal where this scale is thickest. This burning of the metal makes it more easily attacked by the corrosive elements in the water. Therefore with the cracking off of this scale, either

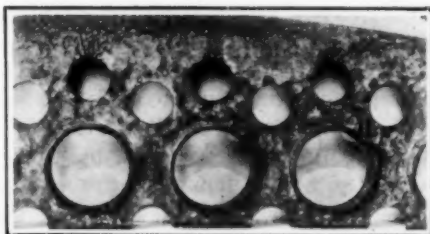


Fig. 1—Flue-Sheet Knuckle After 4 Years Service in Bad Water Territory

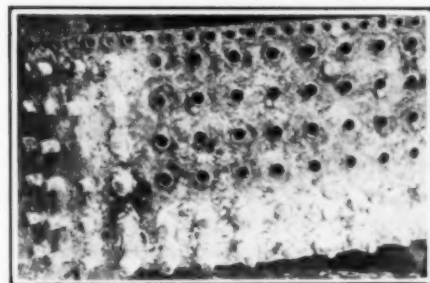


Fig. 2—Corrosion of Flue Sheet Around Staybolts

by expansion or by bombarding, the water comes in contact with this burned metal and the ideal condition is set up for electrolytic action with the dissolving and removing of the iron from the staybolt as well as from the firebox sheet adjacent to it. This results in a groove being made about the staybolt at this point and a similar groove in the sheet near the point where the staybolt joins the

sheet. Fig. 2 shows the corrosion of the sheet around the staybolts from this cause.

At first thought, it would seem evident that scale should be a preventive of corrosion and that where heavy scale formation occurs, corrosion should be absent. Experience shows, however, that such is not the case. After a thick coating of scale is formed, the repeated expansion and contraction of the flue due to alternate heating and cooling, causes cracks or bulges in the scale. These bulges or blisters insulate the tube more perfectly from the water and the result is a badly burned area which is disclosed as a pit when the scale finally cracks away. Fig. 3 shows a badly pitted flue illustrating this process of corrosion.

Oxygen dissolves to a considerable extent in cold water and when introduced into a boiler with the feed water, is one of the principal causes of corrosion. This is illustrated by three Mallet locomotives which were built with preheater boilers. The water used by these locomotives was practically melted snow and contained very little scale-forming or other dissolved solids. The flues in the preheater boilers were completely corroded through in twelve months. The oxygen was removed by its attack on the steel of these flues and did not reach the main boiler with the water. Flues in this boiler ran 4 years without difficulty and showed practically no corrosion.

A similar condition has been found in stationary boilers and a great improvement effected by passing water through an open feed water heater in which the temperature was held above 200 deg. F. This removed a large proportion of the dissolved gases, and caused a notable reduction in the amount of corrosion in the boiler. The practical method for the removal of dissolved oxygen or other gases from the water used in locomotives, has not yet been worked out. The open feed water heater is beneficial, and recent reports have shown that a reduction in pitting can be effected by its use. Feed water heaters are designed to work on exhaust steam, but in order to get the full benefit from them, they should be capable of operation on live steam

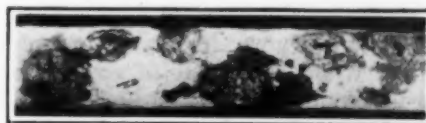


Fig. 3—Badly Pitted Flue

while the engine is standing or drifting.

Some devices are being offered for the separation of air; and while positive results have not yet been observed, tests with such equipment should be followed up. It is also desirable to use injectors which will not permit excessive amounts of air to enter the boiler with the water.

The pronounced effect of oxygen is well shown in two laboratory experiments. Five pieces of standard steel boiler tubing shown in Fig. 4, were placed in containers filled with hot water and the temperature maintained at the boiling point. The test was carried on for 30 days in order to develop the difference in the pitting effect under different conditions.

1. Shows corrosion resulting from distilled water.
2. Shows the effect of a water carrying 1,700 parts per million of

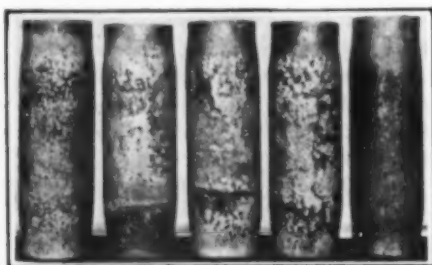


Fig. 4—Effect of Oxygen on Standard Steel Boiler Tube. Refer to Samples from Left to Right

sodium sulphate. This solution represents an ideal electrolyte.

3. Shows the effect of the same water to which was constantly added a current of oxygen and carbon dioxide.

4. Shows the effect of the same water with the constant addition of an excess of oxygen.

5. Is a section of the original tube.

The irregularity of the pitting is due to the fact that no attempt was made to remove the mill scale or surface film from the tube in any case. It is clear that the greatest amount of pitting occurred on No. 4, which emphasizes the part played by oxygen in corrosion.

The difficulty with which all the oxygen is removed from water is shown by the fact that samples of boiled water which has been cooled in the absence of air, still show small amounts of dissolved oxygen. This is further shown in Fig. 5, which shows a small amount of corrosion on two pieces of polished boiler steel which have been immersed for several weeks in raw and treated water

that was first thoroughly boiled and cooled in the absence of air. The treated water did not carry an excess alkalinity.

The principal benefit of water treatment is the removal of incrusting matter, thereby preventing scale, increasing the life of flues and fireboxes and reducing fuel costs. Proper water treatment goes farther than this in the removal of oxygen before the water enters the boiler and in the regulation of the concentration of dissolved solids in the boiler. The concentration of dissolved solids in the boiler is controlled by the use of the blow-off cock. High concentrations of sodium salts appear to accelerate corrosion

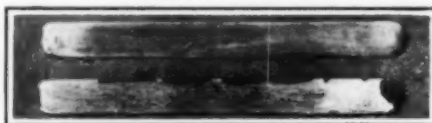


Fig. 5—Corrosive Effect of Residual Oxygen in Boiled Water

and in practice it is desirable to operate locomotive boilers on concentrations below 3,500 to 4,000 parts per million. Further reduction of concentration is not economical on account of the fuel loss.

Where hot water washing plants are installed at the terminals, there is not much loss either from tying up the engine or from the fuel standpoint because of the washing or changing of the water and by this means the life of flues and fireboxes can be very much extended. The hot water washing plant is one of the most important factors in the improvement of corrosive conditions.

There is considerable divergence of opinion among chemical engineers as to how far chemical treatment should be carried. Present practice is to remove the incrusting solids and carry a slight excess of caustic soda on account of its inhibitive effect on corrosion. Too great an excess of caustic soda or sodium carbonate should be avoided in order to prevent foaming, particularly in the presence of high concentrations of dissolved solids and suspended matter. It is possible, however, to carry an excess of 20 to 30 parts per million of caustic soda without interfering with operating conditions. In some cases this may be increased to 50 or 60 parts per million; if so, beneficial results will follow. As a result of excess caustic soda or sodium carbonate there has been some fear of so called caustic embrittlement. There is, however, some

doubt of there being any embrittlement whatever from this source at the concentration found in boiler waters. In the concentrations here recommended and maintained in many locomotive boilers, it is practically impossible for any damage to result from this cause.

It has been shown that caustic soda can produce cracks in boiler steel, particularly if the steel is under tension. This cracking was not observed unless the steel had been subjected to tension beyond its elastic limit. The general consensus of opinion is that the only logical explanation of caustic embrittlement, which will account for its presence in some boilers and its absence in others using the same water, is that it is due to strained or dirty steel in contact with water of excessive causticity.

Laboratory experiments were conducted to show the effect of caustic soda as an inhibitive to corrosion. While these tests were made at room temperatures they show, by com-

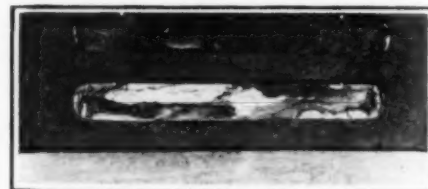


Fig. 6—Legend: A Is the Upper Sample B Is in the Middle and C Is the Lower Sample

parison, the effect desired. Fig. 6 shows three pieces of boiler steel which were polished and then immersed for nine months as follows:

A, which shows severe corrosion, was in a solution of untreated water carrying 500 parts per million of dissolved solids, one-half of which consisted of sodium salts.

B was immersed in a completely treated water with very slight excess alkalinity.

C which shows no corrosion whatever, was immersed in distilled water carrying one per cent caustic soda.

It is believed by some that an excess of sodium carbonate in boiler water is effective in reducing corrosion. Analyses of boiler waters show that sodium carbonate is broken down in the boiler and at least a part of this is converted to caustic soda. Free oxygen is also found in the steam as a result of this reaction. It is therefore better to use an excess of caustic soda than sodium carbonate, thus avoiding the possibility of increasing the oxygen content of the water.

Chromium Alloys in Chemical Plant Equipment

High Tensile Strength and Resistance to Oxidation at High Temperatures, Workability and Relative Cheapness Are Characteristic of Chrome Irons

By C. E. MacQuigg

Union Carbide and Carbon Research Laboratories, Inc.

FROM the very nature of the products, the equipment in chemical plants is subject to attack by corroding media to an extent probably exceeding that in any other type of manufacturing. While it is true that all metallic articles are subject to deteriorating influences, especially from normal corrosion, in the chemical industry the substances handled are likely to be such that few metals or alloys can contain them; therefore, to the manufacturer of chemical plant equipment, the subject of resistant materials is one of first importance. Taking some of the figures available, it is apparent that a vast sum of money is invested in equipment for chemical manufacture, such materials as glass, lead linings, stoneware and fused quartz, to name just a few, being used at present. The recognized and inherent weakness of such materials make the development of stronger or non-fragile types of construction very desirable.

Many metals and alloys already have been adapted to chemical equipment. Platinum and its alloys are among the most resistant and expensive—the latter feature practically restricting them to laboratory use. Gold, while much cheaper than platinum, has the same economic disadvantage. Tantalum, a metal with extremely high resistance to certain chemicals, has excellent physical properties, but it is also expensive. Silicon metal, although of good resistance to attack by some acids, is too brittle for general purposes. Of the other metals used in the pure state, iron, nickel, aluminum and copper are the ones most generally favored. Iron kettles are generally resistant to the neutral compounds and to many alkalies, but suffer from the type of corrosion ever present with moisture, namely rusting; special precautions must be taken, or the iron container will fall from rusting alone; the plain carbon steels suffer from the same dis-

advantage. Pure nickel has certain specific applications; being free from the disadvantage of atmospheric corrosion (moisture rusting), it enjoys quite a superiority over iron but suffers from a high cost differential when compared to iron or steel. Aluminum is widely used, particularly in the nitric and organic acid industries. Like nickel, it has many advantages, but is relatively costly. Copper, while cheaper and possessing the rust resistance enjoyed in a measure by nickel and aluminum, is much less resistant to the common chemicals.

POSSIBILITIES OF METAL PLATING

Metal plating holds possibilities in the way of protection against the corrosive action of chemicals. Nickel plating by electrolysis is quite old and a new development has extended the process to chromium. Plating by spraying the metal, as in the Schoop process, is also resorted to in the protection of chemical plant equipment as well as certain cementation methods which have been described in recent years. The chief difficulty in plating and coating processes has been due to porosity; moreover, metal or other containers which have to undergo any kind of deformation in erection are likely to be injured by breakage of the protective sheathing, and when once the integrity of the surface has been destroyed failure will follow rapidly thereafter.

The field of alloying presents almost unlimited possibilities and is being rapidly developed. Metals which are not by themselves immune to attack, when alloyed in proper manner, are quite satisfactorily resistant. The general principles of chemical stability are hardly more than glimpsed in our present knowledge of alloys, but some general considerations may be noticed. Metals (and alloys) may be divided into two main groups according to whether they owe their resistance to corroding influences to (1) low electrode potentials or solu-

tion pressures, or (2) the formation of a protective coating, formed by the product of the corrosive action itself.

The first-named effect will readily be recognized as due to the relative position of the material in the electrochemical series, as platinum, gold, silver, copper, lead, nickel, cobalt, iron, zinc, manganese, aluminum and magnesium, mentioned in the descending scale of general resistivity, or expressed differently, in their ascending tendency to go into solution in electrolytes. The second effect will be a function of the nature of the film or product of the reaction. For example, although aluminum has a very high solution pressure, and thus an enormous tendency to go into solution, it is actually quite insoluble in nitric acid, because the very thin protective coating of more or less hydrated aluminum oxide which is instantly formed successfully resists further oxidation of the subjacent metal.

From the list of pure metals at present commercially feasible having physical properties that make them amenable to fabrication, we must choose the following: iron, nickel, aluminum, copper, lead, zinc or tin. [F. F. Becket: "Rust Resisting Metals" *Chemistry in Industry*, vol. II (1925)]. With further metallurgical advance, we may obtain other ductile metals in the pure state and these may have valuable special applications for corrosion resistance. Platinum, gold, silver and tantalum promise to remain prohibitive in cost for general use.

ALLOYS HAVE MUCH PROMISE

With the somewhat restricted possibilities seen above, the outlook is much more promising in the direction of the alloy field. The resistivity of an alloy to corroding action is a function of the properties of its metallographic constituents; these may be either pure metals, solid solutions, definite chemical compounds, or their mixtures. The interrelation of chemical resistivity and structural constitution has not yet been the subject of more than a cursory investigation, but it seems safe to say that this study affords greater means of advance than any other, since more information of an indicative nature will be discovered by a correlation of metal structures with chemical properties, than any other means. [Andrews, Lighter & Robertson: "Some Physical Properties of Steel and Their Determina-

tion," *Proc. Roy. Soc.*, London 110 A. pp. 391 to 422, 1926)].

Alloys are loosely classified into ferrous and non-ferrous, depending on whether or not the base is metallic iron. While this classification was formerly more satisfactory, because formerly nothing but iron or steel had properties such as amenability to heat treatment and certain features of microstructure, such is not now the case because some non-ferrous alloys have properties very similar to steel.

Ferrous alloys are particularly subject to attack by acid or oxidizing

In the non-ferrous group almost unlimited possibilities exist for the discovery of corrosion-resistant materials. The control by heat treatment of the various solid solutions and chemical compounds with their respective effects on physical and chemical properties all go to make probable the belief that here will occur in the next generation some outstanding achievements of metallurgy.

Chromium imparts oxidation resistance to the ferrous alloys and this condition holds true for oxidizing conditions in general, either wet

turer of chemical equipment may be commercially classified by their chromium contents. Such division is based on inherent qualities which have led to the adoption of the alloys to their respective fields of service. The results of an attempt at such a classification are seen in the table, which is self-explanatory. It must be understood that the limits of composition and other factors are considered in the broadest sense only, nor has it been considered necessary to go into minute justifications or metallurgical reasons for the various relationships.

In connection with the table, it is of interest to note some of the properties imparted by chromium and the chief alloying elements at present incorporated in the industrial alloys. Chromium is a *sine qua non* for oxidation resistance at high temperatures. When used alone, unless it is present in amounts upwards of at least 10 or 15 per cent, the alloy will not have the best chemical resistance. The oxidation resistant property of chromium is also imparted to its alloys against attack in the wet way, nitric acid being without effect if the metal contains about 12 per cent or more of chromium even in the absence of other alloying elements in appreciable amounts. If the element is used as the single alloying component, it will be found that the degree of immunity imparted is much higher if the chromium content is over about 20 per cent. This is particularly true when the material must withstand oxidation at high temperatures, as will be seen by Fig. 1, which shows the loss in oxidation plotted against chromium content, no other alloying element being present. It must also be pointed out that the oxidation loss shown by the high-chromium alloys is about the maximum which would be obtained with indefinite exposure; this is not true for lower chromium contents since a critical point seems to exist around 20 per cent chromium.

For resistance to wet attack in other than oxidizing media, no general rules can be formulated. Chromium and chrome-nickel combinations have a remarkable versatility. Among the chemicals which are successfully withstood are acetic acid, many hydroxides, fruit and vegetable juices and mine waters. Against sulphuric acid the plain chromium-iron alloys are not reliable under all conditions, although some

COMMERCIAL CLASSIFICATION OF CHROMIUM ALLOYS

Characteristic Chromium Range	Principal Properties	Some Typical Applications
0 to 5 per cent Cr. With or without one or more alloying metals, as nickel, vanadium, molybdenum, etc.	High strength, ductility and toughness and (or) hardness.	Ball bearings, tools, armor, armor-piercing shells, high-speed cutting tools, automobile and airplane parts. Stamp shoes, crusher parts and rolls for ore preparation, grinding equipment, saws, files, multi-ply plates for safes and vault manufacture, etc.
14 to 16 per cent Cr. added to cast iron.	Resistance to oxidation where the physical properties of cast iron are satisfactory.	Certain types of oxidation resistance requirements where the application will not bear the expense of the higher quality alloys, as in annealing boxes for malleable cast iron foundries, roasting or muffle furnaces for temperatures up to 800 deg. C. (1,475 deg. F.).
12 to 16 per cent Cr. Carbon content carefully controlled.	Resistance to corrosion together with excellent physical properties.	Cutlery, kitchen utensils, restaurant and hotel fittings, chemical plant apparatus to withstand nitric acid and many other chemicals. Good against oxidation up to about 800 deg. C. (1,472 deg. F.). Also being used extensively in engineering applications—as in turbine blades, internal combustion engine valves, etc. Builders hardware and decorative parts, sporting goods, marine equipment, etc.
10 up to 20 per cent or more Cr. together with considerable percentage of other alloying metals, nickel being the most frequently used. Silicon and manganese are present in some analyses up to several per cent.	High electrical resistivity and non-oxidizing. High tensile strength at elevated temperatures is a feature. Some have hot and cold working properties.	Electric heating elements. All kinds of heat treating equipment such as case carbonizing boxes, annealing boxes, pyrometer tubes, furnace parts, etc.
20 per cent Cr. and upwards. No appreciable alloying elements other than carbon.	Resistance to oxidation and to many forms of chemical attack, especially nitrates and sulphur. Softness and workability in low carbon ranges; hardness.	All types of apparatus which are subjected to oxidation up to about 1,100 deg. C., such as stills, muffles, retorts. Crushing and grinding equipment. Nitric acid plant equipment. Mine pumps.

agents. On the other hand they have those desirable attributes of workability and strength and, in addition, they are the cheapest. Effort has been directed in the rather recent past towards alloying with iron some element or elements which would enhance its chemical stability without sacrifice of physical properties and undue increase in cost. Numerous elements were and are being tried, such as nickel, molybdenum, copper, cobalt, tungsten, titanium, manganese, vanadium, silicon, both singly and in combination. None has shown the results that have been obtained singly by chromium. Very desirable effects are also achieved with the chromium-nickel combination with iron, sometimes modified by silicon.

or dry, at low or high temperatures. The resistance of the element chromium and its alloys to chemical attack by solutions resides in the inertness of the products formed and held on the surface or in other words is dependent on the protective film. What has been done in attempting a theoretical explanation [Pilling & Bedworth: "Oxidation of Metals at High Temperatures." *A.I.M.E.*, vol. 68; see also *Inst. of Metals*, vol. 1 (1923)] of its resistance to oxidation confirms the well established experience in industry, namely, that after a relatively light initial scaling, the metal is protected from further oxidation by a tough, dense and closely adherent enamel-like coating.

Chromium alloys which are at present of interest to the manufac-

installations have been quite successful. Unfortunately they are easily attacked by hydrochloric acid. Sulphur and sulphur gases are practically without effect on straight high-chromium alloys. The presence of nickel, however, is disastrous due to its vulnerability to sulphur.

Chromium imparts high tensile strength to its alloys but in the higher ranges of chromium content somewhat decreases their ductility. Alloys containing 20 per cent chromium and upwards are readily worked by the usual steel mill equipment to form plates, sheet, rods, wire, seamless tubing, etc. A peculiarly advantageous property of chromium is that of imparting high tensile strength at high temperatures; this opens up a field of applications which is becoming extensive. The presence of nickel greatly enhances the strength and stiffness and diminishes the elongation at high temperatures, thus increasing the resistance to flow under sustained loads at high temperatures.

A matter important to the chemical equipment manufacturer is the weldability of the chromium alloys. They do not hammer-weld but may be readily joined by fusion welding, either gas or electric. Because of the increasing commercial interest in the subject, some general observations will be in order.

The welding of chromium-iron alloys is attended with more difficulty than is the case with ordinary steels due to the formation of infusible chromium containing oxides. The oxide formed is difficult to float and unless eliminated may give rise to such defects as blowholes, laps, and similar defects. The chromium-iron alloys may be satisfactorily arc welded using for an electrode a wire of the same material coated with a flux which is capable of combining with or dissolving the oxides formed. Such electrodes, when suitably coated and used with the proper polarity, will give good dense welds. Some flux coatings will yield good results with either polarity, while others will work with reversed polarity only (electrode positive). Welds made by this process will possess good strength, are easily machinable but will lack in ductility. For ordinary batch mixing or storage tanks, this lack of ductility in the weld would be of no consequence. However, in vessels destined for high pressure and temperature, lack of brittleness is important, and no such

work should be undertaken without first consulting with someone experienced in the making and properties of welds in high chromium-iron alloys.

In order to oxy-acetylene weld the high chromium-iron alloys, it was formerly found that satisfactory welds could be obtained by using an excess of acetylene in the welding flame. While this procedure does prevent oxidation and makes the welding easy, at the same time it charges the weld metal with considerable carbon, making it quite brittle. This practice or method of welding, while satisfactory in some instances, is not generally recom-

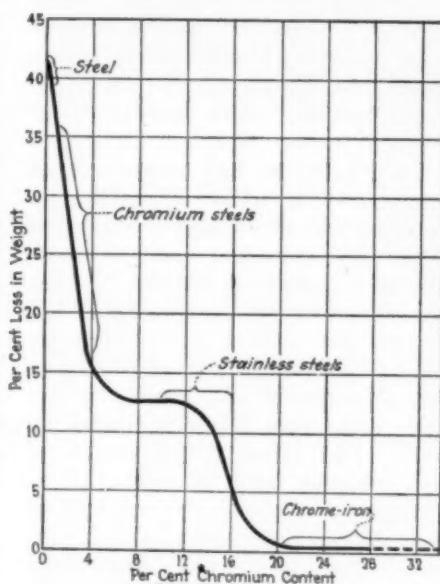


Fig. 1—Loss in Weight by Oxidation
Samples were 1-in. cubes heated 48 hours
at 1,000 deg. C.

mended. Neutral-flame welding may be used by coating the line of the weld and the welding rod with special fluxes capable of protecting the hot metal and dissolving any oxides formed. Another solution to neutral-flame welding is to use welding rods containing appreciable quantities of manganese and silicon, oxidation products of which yield a fusible protecting slag. It is recommended that a small amount of flux be used on the line of the weld to take care of oxidation of the base metal. Research work is proceeding in this field and it is believed that the peculiar problems met in this type of welding will soon be overcome to permit safe welds for high pressure and resistance to shock.

In conclusion, I wish to express my appreciation of the assistance of the members of the Union Carbide and Carbon Research Laboratories who have made tests on chromium alloys.

Resistance of Special Metals to Sulphuric and Acetic Acids

Tests made in a large industrial plant show that copper is effective against dilute acetic acid, either hot or cold, hot meaning from 50 to 80 deg. C. But for strong acetic acid as in vinegar manufacture, aluminum appears to be better than copper. Impurities, either in the aluminum metal or in the acetic acid, accelerates corrosion. For pipe lines and storage tanks, aluminum is indicated for all strengths of pure acetic acid from 28 per cent to the glacial acid.

Aluminum drums for shipping acetic acid have proved satisfactory. The bung is of special design of brass faced with aluminum. Paraffined oak barrels are excellent also.

It should be said that several metals which in the laboratory appear to be satisfactory for acetic acid containers and equipment can not be used as discoloration occurs. This applies to hard rubber equipment as well as to several metals.

Resistance of Special Materials of Construction to Sulphuric and Acetic Acids

Material	20 Per Cent H ₂ SO ₄	Hot Glacial Acetic	Hot 80 Per Cent Acetic	Hot 50 Per Cent Acetic
Aluminum...	Excellent	Excellent	Excellent	Excellent
Bakelite...	Fair	Fair		
Gov. Bronze	Poor			
Resistal				
No. 5...	Poor	Good		
Duriron...	Good			
Aterite...	Excellent	Poor		
Copper...	Poor			
Alum. Bronze	Good	Fair		
Phosphor-Bronze...	Poor			
Duraloy...	Poor	Excellent	Good	
Everdur...	Poor			
Stellite...		Good	Excellent	
Krupp Stainless V-2-A				Excellent
Krupp Stainless V-4-A				Excellent
Firth Stay-brite...		Good	Excellent	

Aluminum Alloy for Ammonia Stills

A large chemical company had difficulty with cast-aluminum equipment in concentrating ammonia. The equipment was the usual No. 12 alloy, containing about 8 per cent copper and 4 per cent zinc. The corrosion was found to be due to electrolysis. Pure aluminum was found to be satisfactory, except for the difficulty in casting, due to excessive shrinkage. However, experiments disclosed that an alloy containing from 1 to 3 per cent of tin gave satisfactory castings and showed no signs of electrolysis.

High-Chromium Irons and Steels for Severe Service

Stainless Steels Have Extremely Wide Range of Properties Which Make Them Adaptable to Unusual Problems in Chemical and Allied Industries

By T. Holland Nelson

Ludlum Steel Co., Watervliet, N. Y.

UNFORTUNATELY some engineers think of "stainless" as a word applying to one particular type of material, differing only by the name of the manufacturer, and losing sight of the wide range of materials available today and the still more important point that the choice of an unsuitable material, may not only lead to serious fabrication problems, but also to unsatisfactory results as far as chemical resistance is concerned.

Manufacturers operating within the Brearley Patents are today fairly well standardized upon a material containing between 12 and 14 per cent chromium with the carbon content varying according to the physical properties. Within this range materials can be produced having a tensile strength as high as 200,000 lb. per sq.in., but such material is distinctly air hardening and this not only restricts the hot working of the material to within a limited range of temperatures, say, from 2,100 deg. F. to 1,750 deg. F., but it also renders extremely difficult the use of such material as a unit part for structural work where portions of the fabrication must necessarily be accomplished hot; as for instance the building of tanks, where riveting and similar operations are necessary. There is, however, a remarkably wide field of utility for this class of material, but a little careful thought and consideration will bring very clearly to light the difficulty of fabricating this type of material into thin sheets or fine and delicate sections, which are practically impossible to finish at temperatures over 1,700 degrees F.

Considerable research work has been done, and today there are available low-carbon chromium materials containing less than 0.10 per cent carbon and upwards of 16 per cent chromium, and which with suitable additions of silicon eliminate almost entirely any hardening effect and make available materials which can be worked from a maximum temperature of 2,100 deg. F. down to a

black heat without fear of rupture or cracking.

This material has found wide use in sheets and special sections where heavy draughts and a wide, hot working range of temperatures are necessary. Due to the fact that the material possesses practically no air hardening tendency, it can be readily utilized for parts such as rivets, which can be driven hot with but slight modification of standard practice.

This material has recently been adopted in a series of tanks for chemical use, which will be described later. The chemical analysis would be approximately as follows: carbon less than 0.10 per cent; silicon 0.50 to 1.50 per cent as required; manganese 0.30 to 0.50 per cent; sulphur and phosphorus less than 0.03 per cent; chromium 16.50 to 18.50 per cent. The physical properties of this material vary considerably according to the amount of mechanical work in the production of any particular section or shape. Tests from angles recently rolled gave approximately the following figures: tensile strength 110,000 lb.; yield point 85,000 lb.; elongation 3 to 4 per cent; reduction of area 15 to 20 per cent. After suitable treatment, the figures were as follows: tensile strength 76,000 lb.; yield point 45,-

000 lb.; elongation 25 to 30 per cent; reduction of area 55 per cent. It will be noted that these figures compare favorably with ordinary materials used for structural purposes.

There are a variety of materials available today, which in fairness to the industry in general, should be mentioned; for instance, there are materials within the 9 per cent to 16 per cent range of chromium containing less than 0.10 per cent carbon, which have little air hardening tendency; there are others available containing slight quantities of copper, for which various claims have been made, and there are still further materials, containing chromium varying from 20 to 30 per cent. Practically all these materials are such that the hardening effect has been more or less eliminated, but there are many other features to be considered in the light of fabrication and application. For instance, it probably would be as well to point out that the lower the carbon and the higher the chromium the higher the corrosion resistance. But it is equally true that the higher the chromium (over 16 per cent content) the greater the mechanical hardness imparted to the material by mechanical work and in many cases, sheets rolled from the higher chromium ranges exhibit serious lamination and a brittleness that is not always removable by heat treatment. From this maze of stainless iron and steels, therefore, it will be seen that it is not the easiest matter to select the most desirable material for any specific purpose.

The following points, however, will be a guide to the selection of materials for specific purposes:

1. Where unusual physical proper-

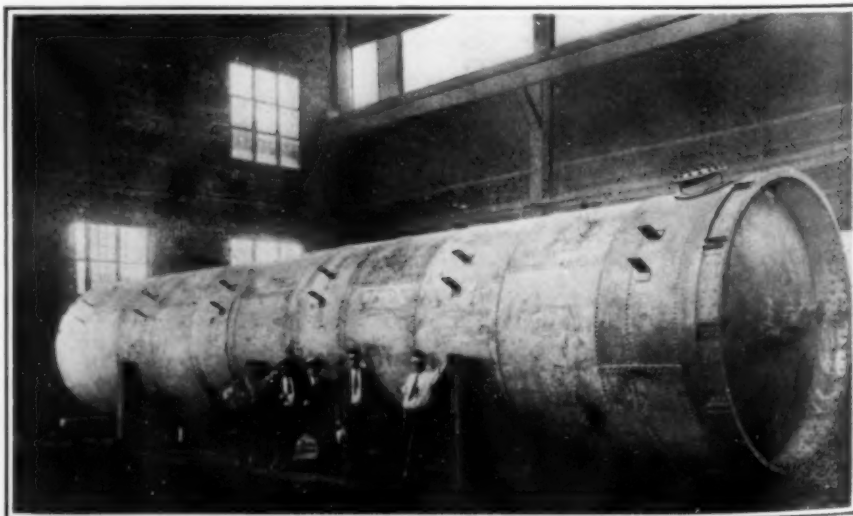


Fig. 1—A 50-Ft. Tank of Chromium Iron

ties are essential, the 12 to 14 per cent chromium material, with suitable carbon content, is the most logical choice. To obtain the maximum corrosion resistance, however, such material should be heat treated and the difficulties of producing and heat treating such articles as sheets or the driving of rivets, at temperatures above the critical point of the metal, should be borne in mind, otherwise disastrous results will follow.

2. Where physical properties under a tensile strength of 100,000 lb. per sq.in. are satisfactory, the low-carbon material, containing upwards of 16 per cent of chromium, is to be desired. This material does not require heat treatment, is highly resistant to corrosion, and hot units or parts can be driven into a cold surrounding mass, without fear of air-hardening and consequent embrittlement.

3. Where heat resistance and unusual physical properties at elevated temperatures are of paramount importance, the high-silicon chrome, the straight higher chromium series and the nickel-chromium series should be used. I do not wish to infer that these materials have not a very useful field in corrosion resistance, but cost and difficulties of fabrication are limiting factors.

It would probably not be out of place to give a few details concerning the fabrication of large equipment. For the past 10 months, I have been engaged in the fabrication of tanks as large as 50 ft. long by 10 ft. in diameter and which required many structural shapes hitherto uncalled for in such an expensive material as chromium iron. It was imperative that the material should be suited to general production methods with the minimum modification. The physical specifications which were to be met were as follows: tensile strength 60,000 lb. per sq.in.; yield point 40,000 lb. per sq.in.; elongation 25 per cent; reduction of area 50 per cent; bend tests between 90 deg. and 120 deg. without fractures.

Fortunately, this allowed the use of the low-carbon chrome silicon materials and some of the outstanding features in this specification were:

1. Sheets of various sizes and gages from $\frac{1}{4}$ in. to $\frac{1}{8}$ in. and as wide as 12 ft., 1 in.

2. Flanged and dished heads of standard shape and design, 10 ft. in diameter.

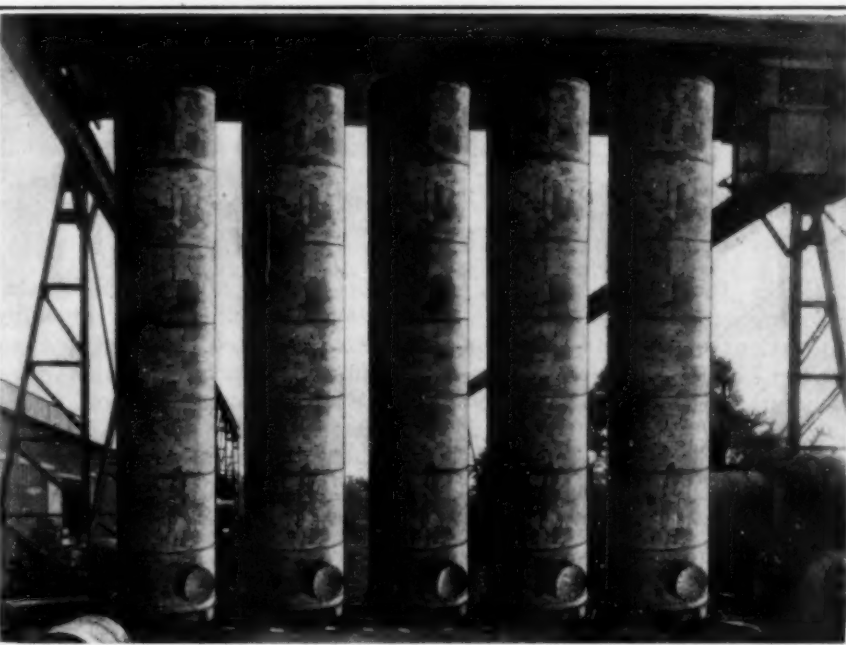


Fig. 2—High-Chromium Iron Tanks for Nitric Acid

3. Assorted sizes of angles.

4. Various types of channels, up to 12 in.

5. Castings of standard shape and design for manholes and nozzles.

6. Bolts, nuts, rivets, etc., etc.

7. Seamless tubing.

Further, it was necessary that the material should be capable of ultimate fabrication in a tank or boiler factory with the minimum modification of standard practice; that the final tank should meet definite specifications and be liquid tight under stipulated pressure.

From a variety of metals available under the heading of stainless irons and steels, the very nature of the work restricted the choice to remarkably few. It should be realized that there is a very wide variation not only in chemical composition, but also in fabricating properties.

Riveting is probably the most outstanding problem in the ultimate fabrication of equipment, such as described and illustrated. It will readily be seen that the ordinary air hardening types of chromium steel could not be used for rivets, as the driving of a hot rivet into a cold plate is practically equivalent to quenching. This would result in the rivet being hard and brittle and therefore, with practically no ductility. On the other hand, the low-carbon high-chromium silicon material, although it has no tendency to air harden, if heated to a temperature at which ordinary rivets are driven (1,900 to 2,000 deg. F.) tends to develop grain structure, and although a rivet driven in this

manner would be soft, there would be a tendency for it to be weak at the sharp angle between the heads and the barrel. A careful study of this problem, however, has proved that the low-carbon chromium-silicon material suitably designed and heated carefully to a temperature not exceeding 1,500 deg. F. can be readily driven, develops no costly crystalline structure and remains soft.

Much has been done on welding. The early difficulties experienced with porous and oxidized welds have been overcome by suitable adjustment of welding torches and the use of various fluxes, but grain growth and hardness are factors not so readily overcome.

In the meantime, it should be possible to obtain drums in which a combination of riveting and welding could be used to advantage and I believe with satisfaction. As far as chromium iron is concerned, I believe the reinforced unit will always be superior to an entirely welded unit.

In studying chromium iron and its adaptability to special purposes, reference should be made to the following works: Symposium A.S.T.M.; the various works of Harry Brearley; Dr. F. M. Beckett; Dr. E. C. Bain; C. E. MacQuigg; Jerome Strauss, and a recent paper by Norman Mochel, A.S.S.T. A study of these works will enable a prospective designer or user to arrive at an intelligent decision with a saving of considerable time, expense and trouble.

Resistance of Metals to Nitric Acid

Studies on Aluminum and Its Alloys, High-Silicon and High-Chromium Steels, Metallic Chromium and Chromium-Nickel Steels

By J. G. Thompson

Fixed Nitrogen Research Laboratory

THE following data are preliminary results on the resistance of various metals and alloys to corrosion by nitric acid of various concentrations, with special reference to the usefulness of commercial metals and alloys for equipment for nitric acid production. The tests were simple total immersion tests, at room temperature, and the specimens which show promise will be subjected to further, more severe tests.

The material for these tests consisted of a miscellaneous collection of metals and alloys, covering a wide range of physical properties. Some of the samples were too hard to be machined, but might be useful for valve parts. A sample of metallic chromium was included in the tests in view of the possible use of chromium plating over softer, less resistant metals. Some of the specimens were obtained from cast plates, others from rolled or drawn pieces.

The surface of the samples, as received, was finished by grinding to remove surface scale and to approximate the machined finish of completed apparatus. Most of the samples were between 5 and 10 sq.cm. in surface area, but varied considerably in shape and dimensions. Whenever possible, round or square rods about $\frac{1}{2}$ in. in diameter and about 1 in. in length were used.

EXPERIMENTAL PROCEDURE

The samples, cleaned with alcohol and ether, were suspended on glass hooks in individual beakers, which were covered with inverted, larger beakers to keep out dust and to prevent undue evaporation. The duration of the tests varied from 1 min. or less, for samples which were vigorously attacked, to 1 week for the more resistant samples. After exposure, the samples were washed in running water, alcohol, and ether, and were then dried and weighed.

The nitric acid, unless otherwise specified, was strong acid, 68.4 per cent HNO_3 by weight, derived from sodium nitrate and diluted with distilled water. The acid was free from chlorides and sulphates when tested with silver nitrate and barium chloride solutions.

Analytical data and corrosion results for acids up to 68 per cent HNO_3 by weight, are given in Tables I and II. The corrosion results, instead of being expressed numerically, are divided into groups, where

A = less than 0.1	} milligrams loss per square centimeter per day
B = 0.1 to 1	
C = 1 to 10	
D = 10 to 100	
E = 100 to 1,000	
F = 1,000 to 10,000	
G = 10,000 to 100,000	
H = More than 100,000	

Aluminum and Its Alloys.—The data indicate the failure of all the aluminum samples, including the purest obtainable metal, to withstand the attack of nitric acid of any concentration up to and including 68 per cent acid. The corrosion of all the aluminum samples is more serious than the loss in weight would indicate, since much of the attack occurs as pits instead of being uniformly distributed over the entire surface.

Chrome Irons and Steels.—The

Table I—Analysis of Samples

Sample No.	C	Si	Mn	Cu	Cr	Ni	V	Fe	Al	
Aluminum and its alloys										
A 1	.....	0.27	.....	0.20	.....	.....	.....	0.04	99.98 (a)	
A 2	.....	0.19	.....	0.10	.....	.....	.....	0.38	99.49 (b)	
A 3	.....	0.32	0.51	4.1	.....	.....	.....	0.34	99.33 (b)	
A 4	.....	0.20	.....	8.2	.....	.....	.....	0.26	94.12 (b)	Mg. 0.61
A 5	.....	0.76	.....	7.6	.....	.....	.....	3.22	91.33 (b)	
A 6	.....	11.3	.....	0.10	.....	.....	.....	Tr	86.39 (b)	Sn. 2.01
A 7	.....	.....	.....	.....	.....	.....	.....	.....	88.56 (b)	
Chrome Irons and Steels										
S 1(c)	0.01	0.01	Tr.	.....	.....	.....	.....	.....	.....
S 2(d)	0.02	0.005	0.01	.....	.....	.....	.....	.....	.....
S 3(f)	0.10	0.02	0.44	.....	.....	.....	.....	.....	.....
S 4	0.91	0.19	0.30	0.09	5.5	0.24	0.04	.....	.....
S 5	0.09	0.31	0.87	0.15	10.8	0.42	0.43	.....	.....
S 6	0.30	0.40	0.40	0.13	13.6	0.11	0.56	.....	.....
S 7	0.18	0.08	0.03	Tr.	14.0	0.17	0.25	.....	.....
S 8	0.06	0.23	0.47	0.10	14.3	0.36	0.36	.....	.....
S 9	0.10	0.20	0.15	0.16	14.8	0.16	1.22	.....	.....
S 10	0.35	0.87	0.17	0.15	15.7	0.32	0.50	.....	.....
S 11	0.09	0.50	0.46	0.08	16.6	0.36	None	.....	.....
S 12	0.37	2.89	0.30	0.07	18.6	0.39	0.39	.....	.....	W 3.50
S 13	0.09	0.89	0.40	None	20.1	None	Trace	.....	.....
S 14	0.27	0.43	0.44	0.12	20.2	0.21	0.70	.....	.....
S 15	0.27	0.15	0.62	Trace	23.7	1.13	1.05	.....	.....
S 16	0.18	0.27	0.65	0.06	25.1	0.11	0.37	.....	.....
S 17	0.70	0.80	0.98	0.11	29.3	0.73	0.13	.....	.....
Chrome-Nickel Steels										
T 1	0.38	2.25	0.46	0.07	10.8	36.4	0.05	.....	.....
T 2	0.15	0.29	1.28	0.09	16.4	22.1	0.26	.....	.....
T 3	0.74	0.50	0.71	0.10	17.3	38.9	0.03	.....	.....
T 4	0.23	2.73	0.40	0.05	18.0	24.7	0.10	.....	.....
T 5	1.00	1.35	0.68	0.45	20.2	60.3	1.31	.....	.....	Mo 3.13
T 6	.....	4.12	0.20	0.44	20.5	38.3	0.38	.....	.....
Miscellaneous										
M 1	1.0 (a)	.....	.....	.....	96-97 (a)	.....	.....	.....	.....	W 2.11
M 2	0.52	1.38	1.25	7.8	21.65	58.6	None	.....	.....	Mo 3.06
M 3(f)	.....	.....	.....	.....	.....	.....	.....	.....	.....
M 4	0.59	14.55	0.41	.....	.....	.....	.....	.....	.....
M 5	1.17	12.24	0.17	.....	.....	.....	.....	.....	.....

(a) Maker's analysis. (b) By difference. (c) Electrolytic iron. (d) Armco ingot iron. (e) Cold rolled soft steel. (f) Complex cobalt-chromium alloy. Not analysed.

Table II—Resistance to Nitric Acid

Sample No.	Concentration by weight of nitric acid, per cent							
	1	5	15	25	35	45	55	68
Aluminum and its alloys								
A 1	B	B	C	C	C	C	B	B
A 2	C	C	C	C	C	C	C	C
A 3	C	C	C	C	C	C	C	C
A 4	C	C	C	C	C	C	C	C
A 5	C	D	D	D	D	C	C	C
A 6	C	D	D	D	D	D	C	C
A 7	C	C	C	C	C	C	C	C
Chrome Irons and Steels								
S 1	E	E	F	G	H	G	G	B
S 2	E	F	F	G	G	H	H	B
S 3	D	F	F	G	E	G	D	B
S 4	D	F	F	G	A	C	C	B
S 5	D	C	A	A	A	A	A	A
S 6	C	C	A	A	A	A	A	A
S 7	C	C	A	A	A	A	A	A
S 8	B	B	A	A	A	A	A	A
S 9	B	C	A	A	A	A	A	A
S 10	C	A	B	A	A	A	A	A
S 11	A	A	A	A	A	A	A	A
S 12	A	A	A	A	A	A	A	A
S 13	A	A	A	A	A	A	A	A
S 14	A	A	A	A	A	A	A	A
S 15	A	A	A	A	A	A	A	A
S 16	A	A	A	A	A	A	A	A
S 17	A	A	A	A	A	A	A	A
Chrome-Nickel Steels								
T 1	C	D	D	B	A	A	B	B
T 2	C	C	A	A	A	A	A	A
T 3	C	C	A	A	A	A	A	A
T 4	A	C	A	A	A	A	A	A
T 5	C	B	A	A	A	A	A	A
T 6	A	A	A	A	A	A	A	A
Miscellaneous								
M 1	A	A	A	A	A	A	A	A
M 2	A	A	A	A	A	A	A	A
M 3	A	A	A	A	A	A	A	A
M 4	A	A	A	A	A	A	A	A
M 5	B	B	B	B	B	B	B	B

per cent acid was immersed for a week in 100 per cent acid at room temperature. A sample of each of the aluminum alloys was also included in this test.

The concentrated nitric acid was prepared from the 68 per cent acid used in the preceding tests, by distillation in the presence of sulphuric acid. The distillate contained 1,528 gm. of HNO_3 per liter when titrated with standard NaOH . This value is slightly in excess of that for 100 per cent HNO_3 , the excess acidity being due to dissolved oxides of nitrogen which impart a yellow color to the acid. The distillate was tested and found to be free from sulphates and chlorides.

Upon 1 week of exposure to 100 per cent acid, the aluminum samples showed no signs of attack, except for a slight tarnishing of the surface. Any change in weight was so slight as to be within the experimental error. Results with the iron and steel samples were not so satisfactory. With two exceptions, the samples all showed surface attack, most of them emerging a shiny blue-black. The two which remained bright, M 4 and T 6 showed only slight losses in weight. Some of the solutions remained clear, but many were clouded, usually with a green sediment. The loss in weight of the different samples was enough to place half of the samples in Class B, the others still remaining in Class A.

The samples were exposed for a second week, in fresh acid to see if the blue-black coat when once formed, would protect the rest of the sample from further attack. The acid for this second exposure contained 1,518 gm. HNO_3 per liter, corresponding to 99.77 per cent acid. This second exposure left all of the aluminum samples still unattacked, but produced from 5 to 10 times as much

effect of chromium on the resistance of steel to nitric acid is clearly shown by these results. S 4, containing 5.5 per cent Cr, is not much better than S 1, 2 and 3, which contain no chromium. Samples S 5 to S 10, inclusive, containing from 10.8 to 15.7 per cent chromium, all show marked improvement over the low chromium or chromium-free steels, but still show a decided tendency to corrode in weak acids. All 7 of the samples which contain 16 per cent or more chromium, S 11 to S 17, show satisfactory resistance to nitric acid of all concentrations up to 68 per cent. These samples show no signs whatever of attack. The surfaces after a week's exposure to the acid are not discolored or tarnished, the solution is clear and colorless, and the change in weight of the sample is negligible.

Chrome-nickel Steels.—T 4 is the only high nickel steel which gave satisfactory results for all concentrations of acid. The other chrome-nickel steels each show inferiority to plain chromium steels of the same chromium content. Evidently, the presence of Ni tends to lessen the beneficial effects of the chromium.

Miscellaneous.—Samples M 1, M 3 and M 4 showed excellent resistance to corrosion of all concentrations of acid up to 68 per cent. M 1 was a sample of metallic chromium in-

cluded in the tests to show the possibilities of chromium plating. M 2, a special alloy, was very slightly attacked. The usefulness of M 3, a complex cobalt-chromium alloy, would be limited by its extreme hardness. M 4 and M 5 were two specimens of high-silicon cast irons and plainly show the superiority of the one with higher silicon and lower carbon contents.

Experiments with 100 per cent Nitric Acid.—The satisfactory resistance of a number of steels and alloys to nitric acid of all concentrations up to 68 per cent by weight, brought up the question of whether the same metals and alloys would resist 100 per cent acid with equal success. Accordingly, a sample of each of the metals rated as A in 68

Table III—Analysis of Molybdenum Steels

Steel No.	Per Cent Mo	Per Cent C	Per Cent Si	Per Cent Mn		
6	0.0	0.44	0.30	1.05		
8	0.34	0.44	0.33	1.29		
3	0.37	0.38	0.35	0.71		
E 53	0.39	0.25	0.19	0.48	Cr 0.95	
2	0.67	0.41	0.42	0.72		
7	0.73	0.43	0.46	1.24		
26	0.75	0.50	0.44	0.63	Cr 0.86	Ni 2.39
41	1.05	0.46	0.43	0.75		
39	1.15	0.50	0.59	0.42		
40	1.90	0.65	0.36	0.79		
43	1.90	0.39	0.24	0.66		
42	2.05	0.36	0.40	0.67		
44	3.00	0.36	0.30	0.65		
A 111	5.75	0.71	0.28			
Mo iron	22.0 (a)					
Fe-Mo	63.+	0.15				

(a) made up for 22.0 per cent Mo, not analyzed.

attack on all the iron and steel samples as did the first week. On the basis of two weeks exposure, all of the iron and steel samples would be classed as B or C, except sample M 4, which appeared to be unattacked and remains in Class A.

These two exposures of one week each were duplicated with fresh samples in concentrated synthetic acid to compare the effects of synthetic and niter-cake acid. The concentrated acid for the first week of test contained 1,528 gm. HNO_3 per liter, for the second week of test 1,534 gm. per liter. The results of exposure to this acid checked very closely the previous results with the niter-cake acid.

ALUMINUM GIVES GOOD RESULTS

It appears, therefore, that aluminum and its alloys show much greater promise than the irons and steels, except for the high-silicon cast iron M 4, for handling 100 per cent nitric acid. The tests showed no appreciable difference between synthetic and niter-cake acids. The slight differences which were observed, followed the differences in concentration rather than the change in the source of the acid.

Tests on Molybdenum Steels.—The fact that several of the resistant steels and alloys contained molybdenum, led to tests of a series of Mo steels to see if this element alone would impart any resistance to corrosion. The samples were obtained from test bars, which were all normalized to eliminate the effect of previous heat treatment. The composition of the steels is shown in Table III.

Tests in dilute acids showed only slight differences between the Mo and plain carbon steels. Even the samples which contained 22 and 63 per cent Mo did not show enough resistance to 15 per cent HNO_3 to be at all useful.

The results of one week of exposure to 100 per cent nitric acid, both commercial and synthetic, show that Mo, at least up to about 22 per cent, does not improve the resistance to corrosion of a plain carbon steel. Even the ferro-molybdenum containing 63 + per cent Mo could not be rated higher than C for 100 per cent acid. The samples which contained Cr as well as Mo were somewhat more resistant than the plain Mo steels, indicating the superiority of Cr over Mo, but the Cr is too low to make the resistance satisfactory.

These tests indicate that Mo alone in irons or steels does not impart resistance to nitric acid.

SUMMARY

(1) Aluminum and its alloys offer promise for the handling of 100 per cent nitric acid, but are not suitable for any concentration less than 68 per cent.

(2) A number of iron and steel samples show satisfactory resistance to nitric acid up to 68 per cent, in this range of concentration being greatly superior to even the best of the Al samples, but the irons and steels with the exception of a high-silicon cast iron, are decidedly inferior to the Al samples in resistance to 100 per cent acid.

(3) A silicon content of 14 per cent or more in cast irons, or a chromium content of 16 per cent or more in chrome-irons and steels, apparently is necessary for satisfactory resistance to all strengths of acid up to 68 per cent. Steels with a lower chromium content may with-

stand moderate concentrations, but fail to resist the action of dilute acids.

(4) Metallic chromium resists nitric acid in all concentrations up to 68 per cent, and may be useful as a plating material.

(5) High nickel content does not improve the resistance to nitric acid of chrome-nickel steels. If more than 20 per cent Ni is present, the resistance usually is definitely less than that of a low nickel or plain chromium steel of the same Cr content.

(6) Molybdenum alone does not impart resistance to nitric acid.

(7) Certain alloys of special composition resist concentrations up to 68 per cent. This resistance probably is due primarily to their chromium content, which may be reinforced by one or more of the other elements present.

Editor's Note—For further data on the resistance of chromium alloys to various common reagents, see p. 636.

Accidents in the Chemical Engineering Group

Analysis of Accidents in New York State by Weeks of Disability and Cause

In a paper read at the Chemical Safety Conference of the National Safety Council, Niagara Falls, N. Y., May, 1926, James A. Hamilton, state industrial commissioner of New York, outlined the accident statistics of the chemical engineering industries of New York State during the year ended June 30, 1925.

The following statistics are of particular interest:

Assuming a standard weighting of death and total permanent disability of 1,000 weeks, the 1,183 compensated accidents totaled 55,422 weeks of disability. The total of compensation, excluding medical service,

was \$579,444. Table I shows the relative standing of the industries, as regards weeks of disability:

Table I—Disability from Compensated Accidents in New York State, Year Ended June 30, 1925

Branch of Industry	Total Weeks of Disability
Chemicals	13,585
Dyes, paints and colors	13,041
Petroleum products	5,959
Coke and charcoal	4,117
Soap	3,917
Explosives	3,090
Drugs and medicines	2,781
Extracts—perfumes, etc.	1,795
Glue, paste, etc.	1,377
Animal oils	1,257
Baking powder and yeast	1,248
Ink, blacking and polish	1,203
Vegetable oils	1,172
Fertilizers	341
Pharmaceutical supplies	204
Hardwood distillation	180
Gases	95
Tar	60
Total	55,422

An analysis of the same accidents according to causes, is shown in Table II:

Table II—Causes of Compensated Accidents in the Chemical Engineering Industries of New York State, Year Ended June 30, 1925

Cause	Weeks of Disability	
	Number	Per Cent of Total
Engines, motors and machines	2,598	5
Hoisting and conveying apparatus	6,321	11
Vehicles	265	0
Explosions, electricity, burns	9,832	18
Poisonous or corrosive substances, or occupational diseases	7,961	14
Fall of person	15,385	28
Stepping on or striking against objects	408	1
Falling objects	3,125	6
Handling objects	5,126	9
Hand tools	2,045	4
Miscellaneous	2,356	4
Total	55,422	100

Sub-Soil Corrosion of Oil Pipe Lines

THE corrosion of pipe lines is a problem which is commanding the attention of the companies that have large investments in pipe. In the past, little attention has been paid to corrosion, a hole in the pipe being taken as a matter of course, a leak clamp being applied as a remedy. But the pipe line companies are now alert to the severe losses due to corrosion, and steps are being taken to recondition old lines and to protect all new lines. It has been found that after seven years a pipe has been badly damaged where it is laid through corrosive soils. Of course there are places where the line will last for twenty years or more, but it has been found that a large proportion of the pipe will be corroded badly in seven years; in some places the life of the pipe is much less than this.

In order to protect the pipe lines from the corrosive action of the soil, one company thoroughly cleans newly laid pipe, applying a primer coat of asphaltic paint. As soon as the primer paint is dry, a covering of hot asphalt is applied with a covering of an asbestos felt and tar paper which is bound to the pipe and sealed by the hot asphalt, which forms a smooth layer between the paper and the pipe. To add further protection, another layer of hot as-

phalt is applied on top of the paper by a canvas blanket which distributes evenly along the sides and under the pipe the hot asphalt which is poured into the blanket. This coating provides about a quarter of an inch of an almost water-proof material. It remains to be seen how long this coating will last in the ground. Some of the companies are applying the asphalt and primer paints to the pipe without the paper.

Another company makes use of a petrolatum bearing some soluble chromium salts as a rust inhibitive agent. In this case the petrolatum is applied to the pipe with a fairly even thickness without any further protective covering.

Where corrosion has set in, considerable trouble is experienced by pipe line companies with leaks and shut-downs at the pumping stations. The corrosion so weakens the pipe that from year to year it is necessary to lower the operating pressure on the line and consequently a decreased delivery and a lowered efficiency. Some companies uncover their lines, take out the bad pipe, clean the lines thoroughly by a pipe cleaning machine and apply the protective coverings before lowering and filling the ditch again. This is being done where lines were not originally covered and corrosion is effecting the pipe. The sand blast is effective, but it is impractical and too costly to be

used in the field. However, the pipe cleaning machine, which travels along the pipe as a pipe screwing machine, cleans the pipe thoroughly and at small cost.

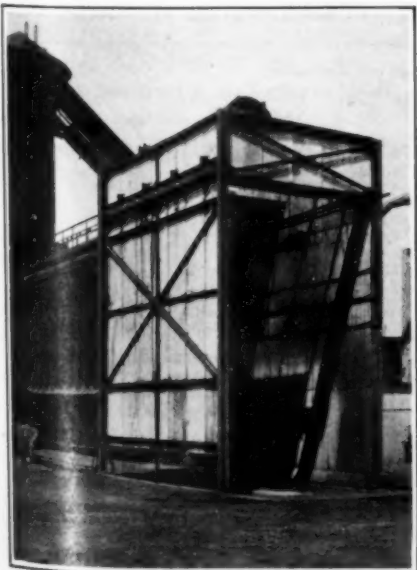
Rubber-Lined Tanks for Acids

In attempting to get a suitable lining for concentrated phosphoric acid (colorless) it was found that the pure para gum (smoked) and the vulcanized rubber made from this gum, both imparted color to the acid, although the lining itself was not noticeably affected. This led to further investigation and ultimately a compounded rubber was developed from specially precipitated latex. This rubber is vulcanized after the tank is lined, is extremely tough and is almost white in color. It imparts no color to phosphoric acid. This material is being used now for muriatic acid tanks as well as phosphoric acid tanks; also for tanks to contain other chemical solutions.

Rubber-lined wood tank cars can be obtained complete including under-frame, for transporting muriatic, phosphoric and other acids. Special equipment such as rubber-lined stirrers and wash trays are also obtainable from one of the large tank manufacturers. Rubber-lined tanks have been in service for six or seven years without any apparent deterioration.

Coke Quencher Station Is Exposed to Corrosive Vapors

Excepting for plant shutdowns for accidents or similar causes, a car of coke is quenched every 5 minutes for the entire 24 hours of the day in the quenching station shown in these illustrations.

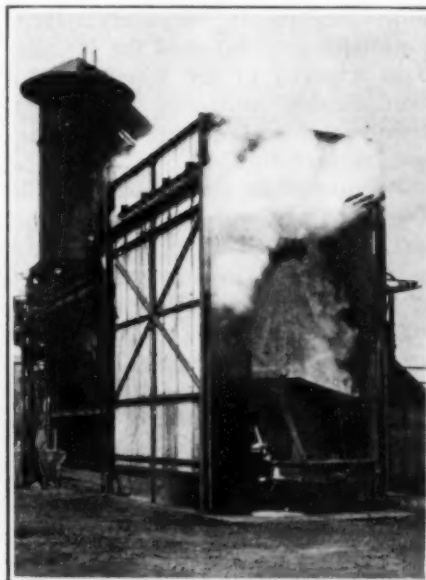


As the hot coke is quenched, the station is enveloped in a cloud of steam that carries with it the corrosive vapors of hydrogen sulphide and sulphurous and sulphuric acids. The steam and hot water together with the fine suspended particles of coke, also have a severe erosive action on the construction materials of the station.

Corrugated iron exposed to these conditions lasts only a short time, depending, of course, on the gage of the metal. Wood lasts a little longer but for various reasons is impractical. Reinforced concrete is widely used on large installations but in recent years a number of coke plants have adopted the type of construction shown in the accompanying photographs. The supporting structure of steel columns and girts is lined on the inside with corrugated Transite board, a compressed asbestos material especially resistant to this type of corrosion. The sheets are attached by hookbolt end and side lap fasteners made from $\frac{3}{4}$ -in. wrought iron, bent to proper shape. Such heavy fasteners, even though protected by a special plastic preparation, are necessary in order to withstand the corrosive action of the vapors.

The station shown in these illustrations has been in constant service for about two and a half years. Recent inspection

showed the Transite to be practically unaffected except that the inside of the sheets had "fluffed" slightly due to the erosive effect of the steam. This action will, in time, wear the sheets through but judging from the present appearance, it will be four or five years longer before the station must be relined.



Non-Ferrous Alloys for Severe Service in Chemical Industries

Deoxidized Copper, Red Brass, Aluminum Bronze, Everdur and Ambrac Have Specific Uses in Chemical Industries

By W. H. Bassett

Technical Superintendent & Metallurgist, American Brass Co.

BRIEFLY, the selection of any material for severe corrosive conditions depends to greater or lesser extent on the following factors:

1. Resistance to corrosion or wear.
2. Physical properties.
3. Availability of material.
4. Effect on contact materials.

From a practical standpoint, the ultimate aim is the maximum service per dollar expended, and, consequently, in balancing Item 1 against cost, the attendant cost of repair and replacement must be included.

Several non-ferrous alloys which are finding extensive use in the industries because of their favorable performance under conditions of severe service are now being manufactured. Among these may be mentioned deoxidized copper, red brass, aluminum bronze, Everdur, and Ambrac.

Deoxidized copper tubes are used extensively in heaters, coolers, condensers, evaporators, and in many kinds of chemical and engineering apparatus. These tubes, as the name implies, are free from oxide inclusions, which results in improved physical properties and increased resistance to corrosion as compared with ordinary copper tubes.

Tubes of this material are extensively used in sugar mill operations where maximum resistance to the corrosive action of acetic acid and ammonia is necessary; large quantities are also used for installations exposed to the action of sulphur dioxide, ammonia, and carbon dioxide such as are found in mechanical refrigerators.

For unusually severe water conditions, red brass pipe gives the most satisfactory service. Although waters used for domestic purposes are usually free from the extreme conditions often encountered in manufacturing operations, when such supplies are obtained from ground waters, colored surface waters of peaty origin, or filtered waters, they are frequently so corrosive as to require something better than commercial brass pipe.

To meet this condition, red brass pipe was developed. Red brass is an alloy containing approximately 85 copper and 15 zinc. Laboratory investigations extending over a period of 10 years have shown some interesting characteristics of the copper-zinc alloys. Pure copper and 15 different alloys ranging from 60 per cent copper and 40 per cent zinc to 100 per cent copper were exposed to the action of polluted sea water at 70 deg. F. It was found that the brasses containing 80 per cent to 85 per cent of copper were affected to some extent but were corroded evenly, the metal retaining its original strength and ductility. Brasses containing 70 per cent or less of copper were in time affected either selectively or generally. During the period of test both pure copper and those brasses containing less than 70 per cent of copper lost considerably more in weight than brass alloys containing 80 per cent to 85 per cent of copper. The present perfect condition of trial installations of red brass pipe after 8 to 15 years' actual service, under the most unfavorable water conditions, substantiates the results of this laboratory research. Not only does the addition of zinc to copper produce an alloy of desirable physical properties, but it is of especial interest that the alloying of zinc with copper within certain limits actually improves its resistance to corrosion un-

der a variety of conditions. Red brass is an alloy of the solid-solution type, that is, behaves as a single component under the destructive influence of corrosion, and exhibits no tendency to selective attack or disintegration.

The aluminum bronzes are useful where a combination of strength and resistance to both corrosion and wear are essential—as for example pump parts, diaphragms, acid pickling equipment, and similar uses. This type of alloy is highly resistant to the action of dilute sulphuric acid and is used extensively for tie rods, bolts, nuts, etc., in the construction of pickling equipment. Several commercial alloys of varying composition, with correspondingly different physical properties, are tabulated herewith:

Nominal Composition		
	Copper	Aluminum
5 per cent aluminum bronze	95	5
8 per cent aluminum bronze	92	8
10 per cent aluminum bronze	90	10

Physical Properties—Rods				
	Tensile Strength, Lb. per Sq. In.		Elongation, Per Cent	
	Hard	Soft	Hard*	Soft†
5 per cent bronze	69,000	53,000	12	55
8 per cent bronze	83,000	60,000	20	61
10 per cent bronze	96,000	80,000	5	33

*Elongation in 10 in. †Elongation in 2 in.

Everdur was developed originally to meet corrosion by hydrochloric acid, the corrosion-resistant alloys and metals available on the market not having been found sufficiently resistant to be of service for the construction of plant equipment in these operations. It has since been found suitable for many other uses involving severe service.

The composition of Everdur is approximately 95 copper, 4 silicon, 1 manganese. Some of its physical properties are given herewith:

Physical Properties of Everdur
Melting Point 1,050 Deg. C., (1,922 Deg. F.); Specific Gravity, Cast, 8.15; Rolled, 8.45.

	Ultimate, Lb. per Sq. In.	Yield Point, Lb. per Sq. In.	Elongation in 2 In., per Cent	Reduction of Area, per Cent
Tensile Strength				
Green sand castings	50,000	30,000	24	35
Forgings (bar forged from 2x2 in. to 1x1 in.)	64,000	40,000	54	60
Hot-rolled rods	75,000	48,000	56	53
Rolled sheets half hard	80,000	56,000	40	..
Wire (hard drawn) 0.025 dia.	157,000	..	..	..
Wire (annealed) 0.025 dia.	80,000	..	..	..
Cold-drawn tubing (as drawn)	98,000	60,000	16	..
Cold-drawn tubing (normalized)	69,000	47,000	42	..

Tensile Strength of 1/2 in. Hot-Rolled Rod at Elevated Temperatures as Determined by United States Bureau of Standards

Temperature, Deg. F.	Ultimate Lb. per Sq. In.	Elongation in 2 In. Gage Length per Cent	Reduction of Area, per Cent
80	72,650	43.5	51.0
500	60,200	33.0	67.4
750	35,930	25.5	69.4
1,000	14,480	18.0	71.4

Thermal conductivity, B.t.u. per sq. ft. per hr., 1 in. thickness..... 72.6
Electrical resistivity, ohms per cir. mil-foot..... 186.
Coefficient of linear expansion per deg. C..... 0.0000170

Ambrac was originated to meet the demands for an alloy having a nickel color and a high resistance to tarnish and corrosion; one which would lend itself readily to hot rolling or forging, and could be readily bent, stamped, spun, formed, and drawn when cold and still have high mechanical and corrosion-resisting properties. The approximate composition is 75 copper, 20 nickel, 5 zinc; zinc in this proportion acting as a deoxidizing agent, and increasing the workability of the alloy and its resistance to corrosion. It is available in the form of sheets, strips, rods, wire, bars, tubes, and castings. Shapes of certain design may be produced by the extrusion process and also by hot pressing or forging. The physical properties of Ambrac are shown in the table.

Ambrac is particularly suitable

for use under severe conditions, especially where exposed to salt solutions or salt spray, alkaline solutions, chlorine bleach solutions, dilute sulphuric acid, and many other types of exposure. It is immune to the physical phenomenon known as "season cracking."

Marked success has attended the use of Ambrac in the construction of washing and bleaching machines, and paper making equipment. After a series of exhaustive tests it has been approved by the Bureau of Construction and Repair, U. S. Navy, for use in the construction of washing machinery. Engineers of one of the largest salt companies in this country have standardized on this alloy for tubes in salt evaporators. Manufacturers of caustic soda have also used such tubes to their entire satisfaction.

Sheet			
	Soft	Light Rolled	Hard Rolled
Tensile strength, lb. per sq.in.	50,000	60,000	84,000
Elastic limit, lb. per sq.in.	24,000	50,000	75,000
Elongation in 2 in., per cent.	30	20	2.5
Hard Rod			
	$\frac{1}{2}$ and $\frac{3}{4}$	1	2
Tensile strength, lb. per sq.in.	80,000	70,000	54,000
Elastic limit, lb. per sq.in.	75,000	60,000	36,000
Elongation in 2 in., per cent.	12	24	48
Wire			
	Hard	Medium Hard	Annealed
Tensile strength, lb. per sq.in.	110,000	85,000	60,000
Elastic limit, lb. per sq.in.	80,000	70,000	20,000
Elongation in 10 in., per cent.	1	1	30
Castings			
Size tested, in.	0.736x0.483		
Tensile strength, lb. per sq.in.	32,000		
Elastic limit, lb. per sq.in.	15,000		
Elongation in 2 in., per cent.	24		

The density at 20 deg. C. (68 deg. F.) is:—8.84 grams per c.c.; 0.3194 lb. per cu.in.; 552 lb. per cu.ft.
The electrical resistivity at 20 deg. C. is:—172 ohms.
The melting point is:—1,150 deg. C. (2,102 deg. F.)
The coefficient of thermal expansion is:—0.0000164 per deg. C.; 0.0000091 per deg. F.
The modulus of elasticity is:—19,000,000 lb. per sq.in.

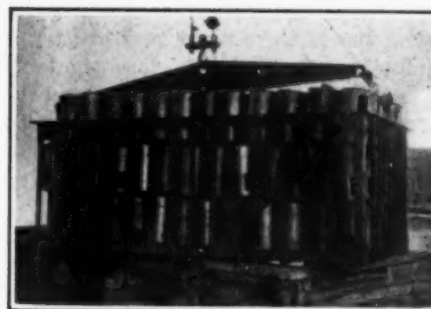


Fig. 2—Pickling Basket for Hollow Ware

To meet the combined destructive effects of strong acid baths and the mechanical abuse of handling, modern industry has sought to eliminate castings and to adopt pickling equipment fabricated entirely of rolled sections. Because much of the equipment is complicated in design, it is necessary to introduce joints, and it was at first thought that this would prove to be a source of weakness in fabricated equipment. Welded joints offer no practical advantage, because at the welded section the material is left in a cast condition. Riveted joints present the possibility that slight corrosion might cause loosening of the rivets, followed by an accelerated attack due to a combination of corrosion and the rubbing action of loosening joints. It has, however, been found that by using extra large rivets, and by setting up all joints with extreme care to insure initial tightness, that this expected loosening does not occur to an extent that makes it a factor in determining the life of the equipment. Heavy sheet mill pickling racks fabricated from rolled bars of Monel metal riveted together have given excellent service for more than 3 years. No tendency to loosen at the joints through corrosion under the rivets has as yet been observed. One type of rack weighs approximately 1,300 lb. using principal members $2\frac{1}{2}$ x3 in. and braced with sections 1x3 in. Three-quarter inch diameter rivets

Heavy Fabricated Pickling Equipment

Not Only the Metal, but Design and Method of Fabrication, Are Important

FOR the manufacture of pickling equipment a combination of great mechanical strength with highest resistance to acid attack is required. The equipment must be strong, not only because the loads are always heavy, but also because there is a universal tendency of the workmen to handle the equipment roughly. High corrosion resistance is essential because the pickling baths are chosen for the most rapid possible attack on the metal to be cleaned. A typical pickling solution contains from 5 per cent to 10 per cent of sulphuric acid. The working temperature is usually as high as 180

deg. F., or even higher for the heavier classes of material. Lighter work is sometimes handled at temperatures as low as 120 degrees F. to 140 degrees F., but in that case the acid content is often increased; or some muriatic acid may be added, with the result that the corrosive power of the solutions is always increased.

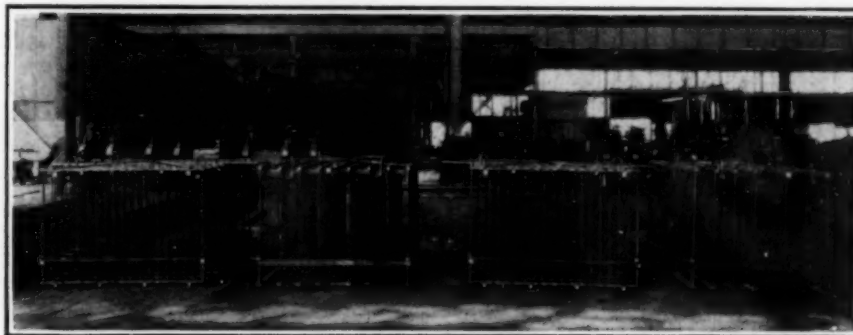


Fig. 1—Monel Metal Pickling Rack for Tin-Plate Stock

were used and the surfaces under the rivet heads were machined to give a smooth bearing and close contact. These racks have been in daily service, lifting 5 to 10 tons of steel sheets on a Mesta type pickling machine, and are showing marked superiority over the cast racks formerly used.

Another field in which fabricated carrier equipment is being rapidly adopted is in the manufacture of hollow drawn ware. This equipment is usually in the form of a basket. Most of these installations have been in continual use for five years or more. The baskets are made from flat sections, angles, sheared strips of sheets and wire in various combinations as best suited to the requirements of the individual plants. Rivets are relied on to fasten the joints, and these joints endure in the hard service of the sulphuric and muriatic acid pickling.

The illustrations show a shipment of fabricated Monel metal racks for one of the largest tin plate mills of the country, and a typical basket used for handling hollow ware. The tin mill rack illustrated has demonstrated its superiority through trial installations during the past 5 years, and is being adopted more and more in place of the old style tin mill racks made up largely of castings. The hollow ware basket shown is of a type that was adopted by a large manufacturer of stoves. Baskets of this type have been in continual service in this particular plant for the past four years and have been adopted as standard.

Materials for Dyehouse Machinery

Relative Advantages of Wood, Ferrous and Non-Ferrous Metals for Equipment Compared

IN ADDITION to a sensitive dye-stuff, dye liquors will contain other soluble materials depending either on the kind of dyestuff or on the kind of goods. These will include acids such as hydro-chloric, sulphuric, nitrous, acetic, formic, tartaric and tannic, or alkaline materials such as caustic soda, soda ash, ammonia, sodium peroxide and sodium silicate. Furthermore, salts such as Glauber's salt, common salt, sodium hydrosulphite and potassium dichromate will be added at one time or another, to accomplish some desired result in shade or finish of the goods. Few materials will resist the action of such a wide variety of

chemical compounds and at the same time prove suitable for the construction of dyeing machinery, in which there are usually a number of moving parts.

Wood was originally used extensively in the construction of such machines, but this material has several disadvantages which have caused it to be discarded. For instance, wood will absorb the dye from the dye liquor and this fact makes it difficult to predetermine the proper quantity of dyestuff. Furthermore, it is usually necessary to have several machines, each for a different color, even though one machine is sufficiently large to handle the total production. Wood also has a tendency to disintegrate rapidly under the action of the dye liquors and its surface will become roughened. In silk dyeing this is bothersome and causes much damage to the goods.

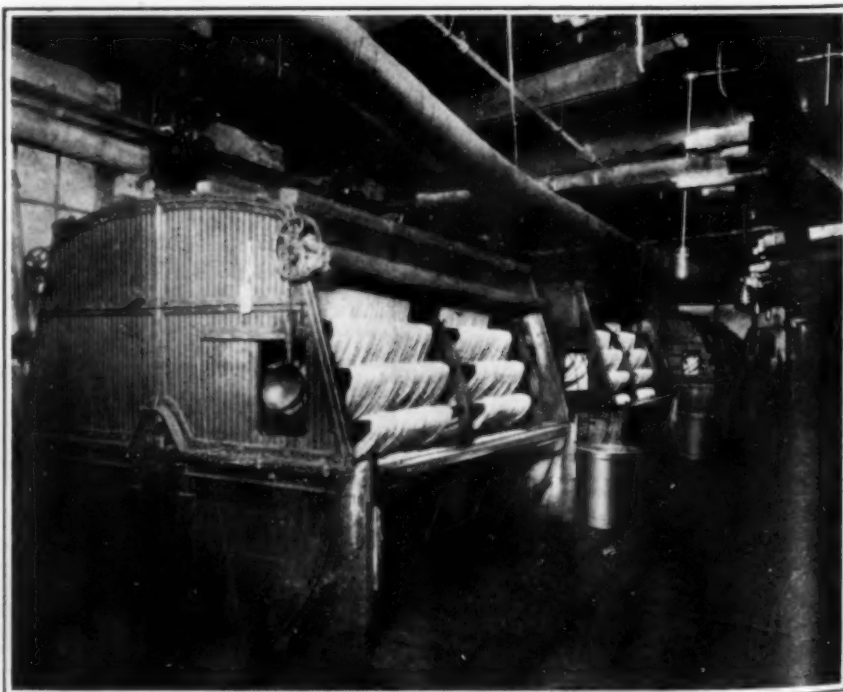
The advantages of strength and ductility associated with metals makes them particularly attractive, and the durability of metal machines is so much superior to those made of wood that the economy effected more than offsets the higher initial cost. The practical convenience of a smooth, hard surface, which remains so permanently, and which can be easily and quickly cleaned is of rather far-reaching importance in the day to day operation of a dyehouse.

But in the application of metals to a dyeing process, due consideration must be given corrosion resistance.

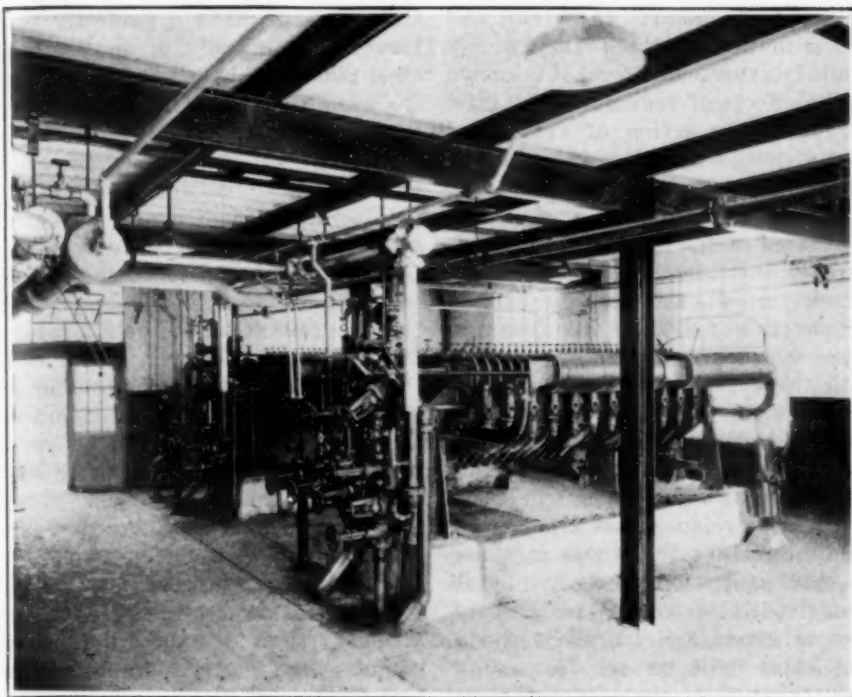
This is necessary from three standpoints—the effect on the metal, the effect on the goods and the effect on the shade obtained. There must be a freedom from any accumulation of solid products, such as rust, on its surface. Rust can be sloughed off, and, in addition, it is usually associated with pitting. In either case, the effect upon fine fabrics would be disastrous. On the other hand, if non-rusting metals are employed, they must be unaffected by the acid and alkaline solutions and by the dyestuffs with which they come in contact. When Monel metal is used the effect is so small as to be negligible in any but the most exceptional dyeing processes. Monel metal is almost universally employed in the dyeing and finishing of silk and cotton, particularly for silk hosiery. In wool dyeing, where fewer colors are the rule and metallic mordants are frequently employed, it is becoming increasingly popular.

Filtering Lubricating Oils at 400 deg. F.

Petroleum refiners have known for some time that greater efficiency could be obtained by using fine clay to obtain the decolorizing action on their lubricating oils and by treating and filtering at high temperatures. The difficulty lay mainly in obtaining a filter which would remove all traces of the extremely fine clay and at the same time be able to stand the high temperatures.



Monel Metal Equipment in Dyehouse



Pressure-Leaf Filters for Heavy Oil

This condition was finally met with a pressure leaf filter equipped with a special Monel metal filter cloth and there are now about 100 such installations in operation.

In at least one case the equipment has been in 24-hour service for over three years without replacement of any parts except minor ones such as gaskets. The original Monel metal cloth is still in service and as far as can be seen is good for a few more years.

The photograph shows an installation of two pressure leaf filters at the Producers & Refiners Corporation, Parco, Wyo. They are handling a heavy oil known as long residuum or reduced crude. Operating at maximum capacity this installation which occupies a space approximately 20x20 ft. is capable of handling 1,000 bbl. of this oil per 24-hour day. Its installation cost was less than half what would have been required for equipment of the old type to handle an equal capacity.

Pump Materials for Hot Sandy Acids

At the Calumet Chemical Co., Joliet, Ill., Pioneer alloy has been used with notable success in pumping hot acid containing sand. The normal life of lead bodies was six weeks whereas Pioneer alloy is still in service after one year. The pump impellers and shaft are constructed of this metal also.

Still Plugs for Unusual Pressures

Resistance to Corrosive Effect of Hot Oil and Correct Expansion Are Big Factors

By Robert J. McKay

International Nickel Co., New York, N. Y.

STILL plugs must be absolutely tight and dependable when the still is operating. On the other hand, they must be easily removed because if they are not they increase the expense of periodical cleaning tremendously. If even a few plugs resist removal they may hold up the cleaning job for hours. Monel metal is usually used in the form of a tapered forged plug which is threaded into the steel or cast-iron header. The opening is about 4 inches in diameter and the plug may weigh from 5 to 8 lb. Cast Monel plugs are sometimes used but are hardly as popular as forged ones. Threads are special and may run 10 to the inch. For speed in removal, it is desirable that the plugs turn out with a large hand wrench.

In modern plants, the temperature of oil may go to 850 degrees as a maximum and the pressure to 350 lb., though these figures are unusual. A temperature of from 700 degrees to 750 degrees is more common. The most corrosive constituents of the oil at these temperatures are sulphur compounds and these may run as high as 3.5 per cent. The destructive effect of partially reduced sul-

phur compounds on metals is probably not sufficiently recognized. Sulphur is second only to oxygen in its corrosive effects, and like oxygen its rate of reaction with a solid metal surface increases rapidly at the temperatures considered. Nickel and copper are both attacked by it in common with most metals. But Monel metal is probably the best material for still plugs, in spite of the fact that the metal is not considered extraordinarily resistant to the attack of sulphur under these conditions.

Obviously the metal of the finished plug must be homogenous and sound after forging and it must be strong at these temperatures. It must be possible to thread the forged metal with speed and exceptional accuracy. The finished thread must be smooth and accurate, or removal will be difficult on this account alone. Monel metal lends itself well to the necessary hot forging and machining operations and finishes sound and true in shape. It retains more than 90 per cent of its room temperature strength at pressure still temperatures.

The coefficient of expansion of Monel metal is about 0.000008 per deg. F. in this range and is thus somewhat greater than that of iron. Due to this property, the plug may be screwed into the header comparatively loosely and when the oil is heated it tightens by expansion. In this way it is held more firmly than if it were actually screwed into place. Since the temperature in the still increases with the pressure, the fit becomes tighter as the pressure increases. When the still is cooled down and ready for cleaning, the plug contracts more rapidly than the header, and when cold, is loose enough to be unscrewed by a hand wrench. The relative increase in expansion of the plug over the header must not be too great because too much pressure will tend to make the two "freeze" together. Also, if the pressure were to become too great the plug would be deformed. This deformation occurs when metals of too high expansion are used and not only interferes with removal but when repeated several times may cause cracking of the plug.

To return to the problem of corrosion, the rate here is of less importance than the type. Even though Monel metal is attacked more rapidly than some other materials on the exposed face of the plug, this rate is not so high but that it can be cor-

rected by making the design heavy. But if the corrosion were of such a nature that it penetrated into the threads, producing corrosion or oxidation products which would block the threads and interfere with turning, it would make the use of the metal impossible. This is the tendency in ferrous alloys. The oxides of iron tend to form in the threads and effectively prevent removal, but with Monel, corrosion only occurs directly on the face, leaving the threads in good condition.

Corrosion of Tin Plate in Containers

Study of Attack of Foods on Tin Cans and Review of Possible Alternative Materials

RECENT studies by C. L. Mantell, chemical engineer, Pratt Institute, and E. S. Lincoln, consulting electrical engineer, Portland, Me., show that tin plate, in spite of certain faults, still is the most promising container material for canned foods. The corrosion of tin by organic acids has been extensively studied without reference to the canning industry. Citric, a common fruit acid, definitely etches tin, the attack being most pronounced along the inter-crystalline boundaries. The tin crystals on the surface of tin plate are elongated, flattened and distorted due to the mechanical working, polishing and cleaning that the tin plate receives in its manufacture and fabrication. Malic acid, occurring in apples readily attacks tin in the presence of air. With lessened amounts of air the attack will not proceed as rapidly. Acetic acid attacks tin and its alloys. While particularly evident in sour milk, lactic acid has also been found to exist in other foods. Oxalic acid has chemical effect on tin.

Many of the corrosive effects in cans of the acids in foods have been examined. With the exception of canned clams, all canned foods show pH values lower than 7; that is, they are acid in reaction. While the effects of the different foods, show slight variations, the general results are the same. The etching due to peaches is somewhat small but the detinning action of spinach is quite severe. The chemical attack of the acids in spinach on the tin of tin cans has been reported a number of times in the German and American literature. The action of pumpkin and squash is quite the same as that of spinach. The con-

stituents of rhubarb, grapefruit and apples markedly attack tin plate. It would be expected from what is known of the effects of vegetable acids that the detinning action of cider, and berries would be severe in a relative sense. This was found to be the case.

Perforation troubles are usually associated with food products containing constituents which chemically attack tin. If we were to have a completely tinned sheet free from pin holes and exposed iron, in contact with those foods we would not expect electrolytic action at first but we would expect chemical attack. If the chemical action is continued long enough, enough tin will eventually dissolve to expose the iron of the base metal. When this happens, we will again have two metals in contact with the electrolyte, with the iron as anode and tin the cathode. The stage will be set for anodic disintegration of the iron and eventual perforation of the can. If there are no neutralizing factors (that is if the attacking constituent is neither consumed nor brought to equilibrium) no matter how heavy a coating of tin is put on tin cans, perforation will eventually occur.

Although this would seem to justify the conclusion that the tin can leaves much to be desired as a perfect container for preserving foods it is well to remember that there is not available at the present time as good a substitute which has all the commercial features of the tin can. Glass containers would eliminate corrosion, but they are not suitable or adaptable for cheap shipping and transportation. Paper containers will not ordinarily stand processing of foods. Metal containers other than those made of tin plate, bring along their own corrosion problems. They are also more costly. Tin cans are relatively cheap because of the quantities in which they are made and consumed.

It would seem that there are possibilities in further work on potential reversal in tin cans containing food products. There is no reversal of potential in fruits and similar products but a reversal can be effected in these foods by the addition of small quantities of a strong electrolyte. If we can get reversal, we can "kill" the electrolytic effect.

Enameled or lacquered cans have been used, the additional coating being made on tin plate. It is no less difficult to make a perfectly continuous coating of enamel or lacquer on a commercial scale on tinplate,

than it is to make a perfectly continuous coating of tin on the base steel plate. It has been shown that we usually have chemical attack on the tin in the case of those foods which perforate. If the enameled or lacquered coating on the tin plate is not perfectly continuous, chemical action of the constituents of the food product, instead of being spread over the whole area of the can, will be localized at those points where the coating is not continuous and the tin plate exposed. With localized action, corrosion will be accelerated and perforation will result more rapidly than in an unenameled can. Commercial experience has shown that enameled cans perforate more readily than those which are not enameled.

Discoloration is largely due to the action of sulphides and sulpho compounds; iron and tin sulphides are both black and this is objectionable in food products. Many metals form white sulphides, zinc for example. Paper liners in the cans of foods products which discolor badly have been effectively used; the paper containing zinc salts. It is evident from the food standpoint that there are decided objections to the use of zinc compounds. An acceptable preventative or means of elimination other than a change of container (say to a lacquered or enameled can) does not seem to be available.

Handling Acetic Acid and Volatile Acetates

A screw gate valve of copper-aluminum-iron alloy is in service at the plant of the Kessler Chemical Co., Orange, N. J., on a copper pipe line leading from a copper tank containing acetic acid, 80 per cent strength, to a large copper boiling tank. Through another line the tank is filled with alcohols such as fusel oil, used in preparing the various acetates, such as amyl acetate, butyl acetate, etc., which are required in the manufacture of lacquers and as nitro-cellulose solvents. The valve is being acted on by the boiling solvents and the acetic acid. After about two months service the valve is continuing to function satisfactorily standing up against 80 per cent acetic acid on the one side, and the acetates formed from it on the other. On the strength of the service rendered, the alloy is to be used in a pump impeller, formerly made of ceramic material.

Centrifugals for Handling Corrosive Materials

**Although Limited in Choice of Metals and Alloys, Equipment
Manufacturers Have Solved Many Severe
Service Problems**

By Lee H. Clark

Technical Department, Sharples Specialty Co., Philadelphia, Pa.

CENTRIFUGAL applications and processes present many problems that require a thorough study of metals and alloys adapted to resist corrosion and erosion. Having "Severe Service" as our topic, it is of interest to centrifugal users, present and prospective, and to the manufacturers of alloy materials alike briefly to outline and illustrate the present scope of the centrifuge for handling corrosive materials and the requirements of alloys and metals for use in the construction of centrifuges operated at relatively high r.p.m.

Monel metal and steel are so far the only materials that meet entirely the specifications required for the construction of centrifugal bowls or rotors. These metals have the required tensile strength, yield point and modulus of elasticity. At the same time they are procurable in the proper shapes; steel, as seamless tubing for bowl shells and forged for the tops and bottoms of bowls; Monel, as bar stock, from which the bowl parts are machined. Both are easily machinable. Of the many other alloys tested and examined, none has yet been found to meet all the requirements necessary for industrial usage.

Practically the whole range of alloys are available for the construction of accessory centrifugal parts with which the liquid actually comes in contact. Where several alloys are available, each equally satisfactory for the purpose, the one is chosen that combines relative cheapness with easy fabrication. Lynite, an aluminum copper alloy, has proved particularly useful for covers, because of its lightness which lends to easy handling and its resistance to many dilute and weak acids. Cast iron, cast bronzes, spun brass, Monel and copper covers and drags of cast iron, brass, Monel and bronze are likewise used to meet specific corrosive conditions.

For centrifugal bowls, a metal's resistance to corrosion roughly parallels its usual known uses. Yet metals

have been known to fail for centrifugal work where they would be quite satisfactory for gravity settling. Only recently the problem arose of treating a solution of ferrous sulphate containing about 5 per cent of sulphuric acid. Laboratory corrosion tests on a piece of the Monel indicated that a bowl made of it would corrode to an unsafe thickness only after six to eight months of constant operation. Yet a bowl, actually applied to the same purpose commercially, was measured and found to be corroded too deeply for further operation after only 60 consecutive hours. Apparently the protective coating that minimized penetration of the corrosive liquid under static conditions was removed, as rapidly as formed, by the friction of the liquid being brought up to speed by the revolving bowl.

EROSION A FACTOR

Erosion of centrifugal bowls is frequently encountered when least expected and in cases where corrosive conditions are not detectable. In the Sharples petroleum dewaxing process it has been necessary to construct the top or head of all bowls from Monel metal to resist the erosive action of the hot water that is jetted against the top of the bowl to supply the carrier liquid on which the wax floats within the bowl. This jet rapidly wears a channel in the bowl head where the jet strikes.

Erosion due to an entirely different action occurred with the many machines used for dehydrating crude petroleum and petroleum "bottom settling." The oil carries a fine sand which is not removed from it during centrifugation at high rates of flow. This sand in the stream of oil rapidly erodes the steel or brass annular adjusting ring over which it escapes from the bowl. Substitution of Monel metal rings has entirely eliminated the trouble from this source.

Monel metal is particularly useful in handling vegetable and fruit juices. Not only does it eliminate the bowl corrosion problem but it

avoids the contamination and discolorization of the product that often occurs when these materials come in contact with iron. Important among such centrifugal processes is the simultaneous clarification and separation of orange and lemon juices. A single centrifugal operation serves to recover the valuable essential oils and to clarify the juice preparatory to bottling.

SEVERE SERVICE APPLICATIONS

Among other severe service applications of the centrifuge is the removal of acid "pepper" from "sour oils." By removing the final traces of sulphuric acid and sludge from acid-treated and settled lubricating stocks, better colors are obtained in the finished oils. When the centrifuged sour oil is neutralized with caustic solutions, a saving in caustic and reduction of emulsion is effected; when neutralized and decolorized by contact filtration using one of the many clays, less clay is required and removal of the clay by filter press is easier.

Monel bowls have been used to minimize the corrosive action of a galvanic couple formed by a metallic deposit in the bowl and the bowl shell, in two important applications, i.e., the recovery of platinum from spent sulphuric acid contact mass and the recovery of silver halides from waste photographic emulsions.

Probably the most severe service to which a super centrifuge has been put is the clarification of a wax heated to 400 deg. F. Because of the presence of fatty acids in the wax, Monel metal was used for the bowl and for other parts, through which liquid flowed.

PLATING A PROTECTIVE COATING

Before the use of Monel, weakly acid liquors such as the fruit juices were commonly handled in copper plated equipment. A heavily copper-plated bowl has considerably longer life than steel but the difficulty of retaining copper plate intact in threads and upon surfaces subjected to wear operates against its effectiveness. Once a break in the plating occurs the steel below corrodes very rapidly due to the galvanic couple, steel-copper existing at the break.

For the laboratory, a wider range of metals is permissible than for industrial practice. Machines receive more careful handling and are subject to closer inspection. Plating over steel is therefore practicable

where suitable metals are not available for bowl construction. Nickel-plated steel bowls are in common use for bacteriological work. Gold-plated bowls have been made for the same purpose. In addition bowls have been constructed of bronze, Monel metal and sterling silver, the last for use in research work with photographic emulsions.

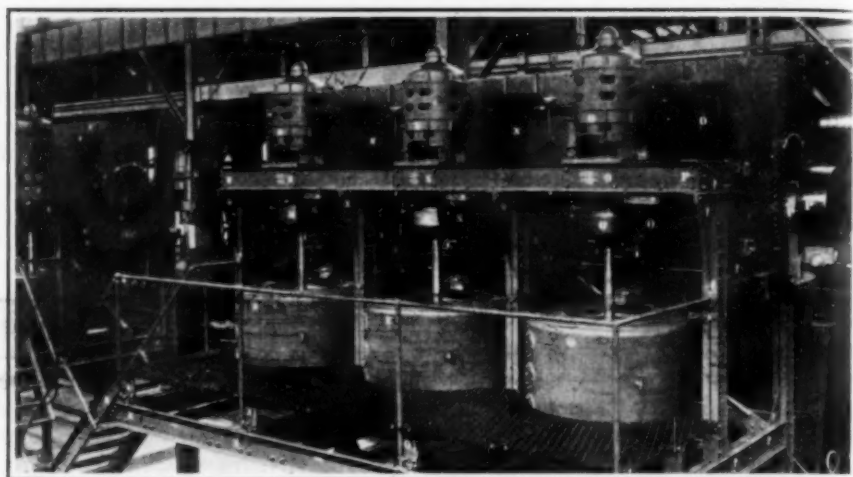
The only exception to the use of Monel metal and steel for bowl construction, has been in the case of the clarification of concentrated zinc chloride solution for which a manganese bronze bowl was constructed. This material has a lower modulus of elasticity than that usually required but failure from this shortcoming was avoided by constructing a somewhat shorter bowl than the standard size used for the majority of production problems.

To the present time the newer stainless and acid-resistant steels have not been produced in the proper shapes or are too difficultly machinable to be used industrially. Great hopes are held out, however, that a number of the many steel alloys now coming into prominence can be produced in shapes that will permit their use in the centrifuge. The field of centrifugal usage can be widely extended by the co-operation of alloy specialists in the production of centrifugal bowls from the special steels and other alloys. There are many industrial problems that have been solved in the laboratory but that are not commercial as yet, due to the lack of sufficiently workable corrosion resisting metals.

Centrifugals in Severe Service

Unusual Applications to Resist Corrosion, Erosion, and Deleterious Action of Vapors

IN 1915 a chemical company was up against the problem of centrifugalizing a phosphoric acid residue, the liquor of which was high in phosphoric and sulphuric acids. Ordinary steel baskets were attacked and quickly deteriorated under this service. It was decided to attempt the coating of the entire basket with Bakelite. At first an attempt was made to paint a lining on the basket with an ordinary paint brush but it was found that in the process of baking the coating crept and left places entirely exposed. When, after several at-



Battery of Special Centrifugals for Saltpeter Refining

The deliquescent nature of sodium nitrate makes it necessary to provide special means of protecting the motor insulation. It is also essential that no wood or other combustible material be used in any connection with this installation.

tempts, this method was proved unsatisfactory, the basket was sand-blasted and the resin solution was painted on the boiler-plate steel basket first with an ordinary brush and then the holes and crevices were filled by means of an air spray. After this first coat had dried the basket was baked in an oven for 18 hours at a constant temperature carefully controlled by pyrometric equipment. The basket was then withdrawn and a second coat of Bakelite varnish applied, this time by means of an air brush. The basket was again baked in the oven for 18 hours and this process was repeated until 4 or 5 coats of Bakelite had thus been applied. The basket was then put into service and is still in use after 11 years, and showing no sign of corrosion.

Another interesting application for a centrifugal is now being made at a chemical plant in Ohio, where it is necessary to remove a solid material from a liquor containing hydrochloric acid. The basket of this centrifuge is made of a rubber-coated steel applied by a special process. In applying this method a steel basket is made with $\frac{1}{8}$ -in. holes and into these holes a special rubber washer is placed which has a $\frac{1}{4}$ - or $\frac{1}{2}$ -in. opening. Sheet rubber is then applied on both the outside and inside of the basket with holes trimmed to correspond to the outside of the rubber washer. The basket is then vulcanized to give a hard-rubber composition that entirely protects the steel of the basket.

Another severe service problem that is being met by one of the centrifugal manufacturers is in the design of special centrifugals for dry-

ing calcium chloride crystals. These centrifugals have perforated copper screens, Monel metal woven screens and special bronze baskets reinforced with Norway iron bands. These centrifugals are driven from above by electric motors which are also of special design due to the deliquescent nature of the calcium chloride being handled. The coils of the motor are especially impregnated to protect them and a special means of ventilation is provided that forces dry air through the motor covering and prevents the possibility of contact with the moist air containing dissolved calcium chloride.

A somewhat similar problem is encountered in the centrifugating of saltpeter. In this case it is absolutely necessary that no wood be used in the construction of the centrifugal or its supports, due to the fact that wood gradually becomes impregnated with the saltpeter and becomes extremely flammable. The motors of these centrifugals must also be protected because the salt is deliquescent and unless protected will be injured by the moist air carrying dissolved sodium nitrate. The centrifugals shown in the accompanying photograph were installed by the Cresson-Morris Co., in a modern saltpeter refining plant recently completed. Larger installations of the same general type have been made in the plant of the Guggenheim operations in Chili.

The manufacture of ordinary table salt presents a very definite corrosion problem to the centrifugal manufacturer. It has been found practical to fabricate the baskets for such centrifugals from special bronze sheets which are reinforced on the

outside by bands of Norway iron. The monitor cases for such centrifugals have also shown considerable corrosion and have had to be replaced at infrequent intervals. It is now proposed to manufacture the monitor case of rolled Monel metal. The cost of such a machine will be several times that of ordinary steel construction but its expectation of life is such as to warrant the increased investment.

Cream Separator Presents Corrosion Problem

Taste, Smell and Health Are Chief Considerations in Selecting Satisfactory Construction Material

By A. E. Flowers

Engineer in Charge of Development, The De Laval Separator Co., Poughkeepsie, N. Y.

CORROSION in the cream-separator industry is peculiarly complicated because of the difficulties inherent in any phase of handling food products. The factors of taste, smell, normal sourness (from lactic acid cultures), bacterial growth, disease germs and vitamins are more important with milk, cream, butter and cheese than with almost any other food product. Furthermore, polish or smoothness of surface and ease of cleaning and disinfecting are of equal importance.

If corrosion is present, the taste and smell of milk are extremely likely to be affected deleteriously. For some metals this effect is more pronounced than for others, since it has been found that a given amount of corrosion loss from some metals affects the taste and smell of milk vastly more than similar amounts of other metals. Copper and most alloys containing copper are generally harmful to milk, not only affecting taste but promoting bacterial growth and souring. Metallic lactates also combine with the casein, displacing the calcium and tending to produce objectionable slimes.

In the work done so far, the loss of pure tin immersed in milk is not only low (although not the lowest) but also far less detrimental on taste than any other metal. For this reason, tin or steel heavily coated by as nearly as possible a perfect coating of tin (free from pin holes, thin spots or bare edges) has been widely and almost universally employed for all containers and apparatus coming in contact with milk.

Other metals have been coming into use lately and meeting with some success. The principal ones are Monel metal, nickel, aluminum and chromium iron. These materials may be better than tin from the standpoint of corrosion loss by weight or reduction of wall thickness, but offer no advantages as to effect on taste and smell.

Aluminum has the special disadvantage of being corroded by alkalis, and as these are present in most washing compounds, aluminum parts may be badly corroded. In this connection it should be more widely known that if sodium silicate, even in very small percentages, is added to any of the caustic washing compounds it will prevent this caustic corrosion of aluminum.

Because of the primary considerations of taste, smell and health very little has been said so far about corrosion as a source of trouble with milk through loss of weight, or wall thickness. Indeed the pockets, recesses and rough surfaces caused by corrosion are more deleterious because of the difficulty of scouring and disinfecting them than on account of the actual loss of metal.

Any changes or improvements must not only meet the critical consideration of the apparatus manufacturers, but also the users of the apparatus, the field inspectors and laboratory testers of various Boards of Health, the medical fraternity and finally the ultimate consumers, that is to say practically everybody in the country.

Protective Paint for Water Tanks

TANKS for industrial water are subject to more or less severe corrosion conditions, depending on the source of the water, which may be either from the wells or streams.

Figs. 1 and 2 illustrate a typical

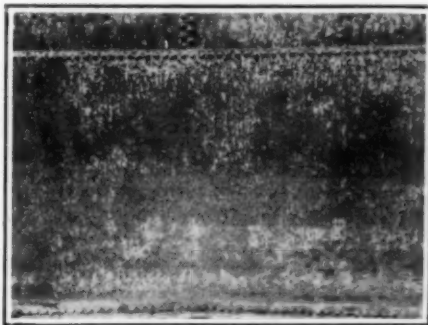


Fig. 1—Poorly Protected Industrial Water Tank



Fig. 2—Close View of Seams Shown in Fig. 1

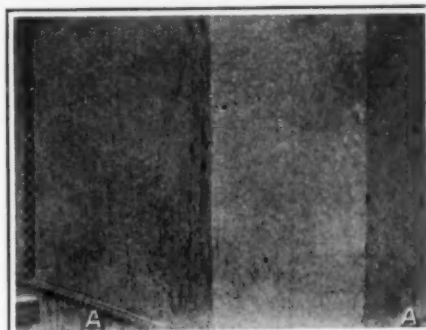


Fig. 3—Comparative Protection of 2 Paints. Paint B Shown in Center

case of an inadequately protected 2,000,000-gal. industrial water tank after about five years' service. Continued use of such a paint would obviously prove expensive. Fig. 3 illustrates the difference that can exist between an adequate paint B and inadequate (and cheaper) paint A after ten years of service. The perfect condition of the plates and rivet heads where paint B has been used is shown in detail in Fig. 4. Paint B is of the following composition:

- 76 per cent pigment (by wgt.).
- 75 per cent zinc dust (metallic zinc powder).
- 25 per cent zinc oxide.
- 24 per cent vehicle.
- 92 per cent raw linseed oil.
- 4 per cent thinner.
- 4 per cent drier.

That a more expensive paint may not always prove markedly superior is indicated by Fig. 5, which shows another (more costly than B and

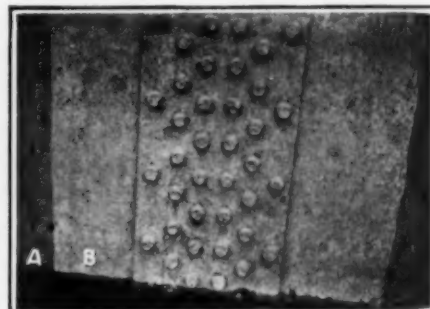


Fig. 4—Close View of Seams Protected by Paint B

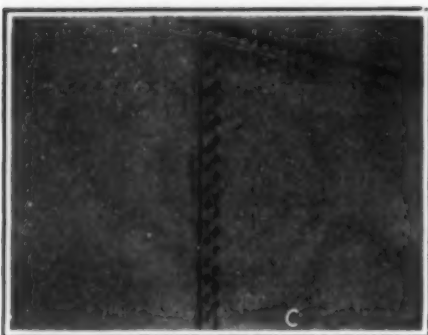


Fig. 5—Failure of a Protective Paint

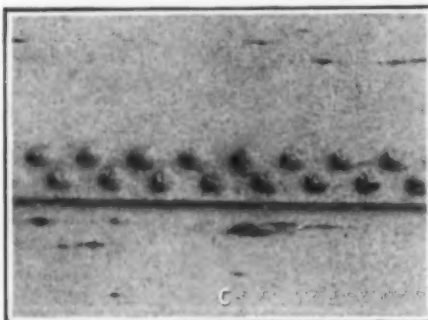


Fig. 6—Close View of Seam Shown in Fig. 5

widely used) paint *C* exposed under similar conditions. The formation of rust pits and incipient flaking that are beginning to appear are shown in more detail in Fig. 6.

Properties of Rubber-Lined Containers

Heavy-Duty Drums and Tanks for Wide Range of Chemicals Have Long Life

ONE of the first articles using rubber as the protective coating was a rubber-lined drum. Drums of 30, 55 and 110 gal. capacity, made of 14 gage metal, are completely lined with rubber. Either the removable or non-removable head type can be supplied. The latter type drums are equipped with standard rubber bungs and cocks for drawing off the acid. The exteriors of the drums are painted with an acid-resisting paint. These drums can be subjected to a pressure of 80 lb. per sq.in. without harming them other than causing the ends to bulge. That is, the lining remains intact under this test. Furthermore, a drum can be filled to 90 per cent of its capacity and dropped 6 ft. tilted at an angle of 45 deg. onto a pavement. The result is a deep dent at the point of contact, but the lining bends with the metal and does not become loosened or cracked. In other words, these drums are acid-proof even after subjecting them to

tests of this kind. The drums are designed to stand up under the most severe shipping conditions.

RESISTANCE TO HEAT

While heat is destructive to rubber, many processes are carried out at high temperatures, in which rubber lining is a decided economy. As an example, one company uses small wooden tanks about 3 ft. square by 3 ft. deep for pickling iron. Muriatic acid is used and is heated to 100 deg. C. with an open steam jet. Under these conditions wooden tanks last less than a week. They are of a cheap construction and are discarded as soon as they leak badly. It was found by lining the same tanks with rubber that it was possible to use them six months and then the failure of the tank was due to an oil scum which came off the fittings. That is, the rubber failed at the top of the tank where it came in contact with this oil. It was found further, that by protecting the top of the tanks with a special oil resisting rubber that the life of the lining could be further prolonged with an added saving to the purchaser. Another case where rubber lining was a decided economy was a process involving the use of formaldehyde at 65 deg. C. Before trying rubber, it was found that special hardwood tanks were the most satisfactory, but these had to be replaced in two weeks' time. A steel tank lined with rubber and fitted with hard rubber connections was put into service and is operating successfully at the end of six months.

CHEMICAL RESISTANCE OF LINING COMPOUNDS

The rubber compound used for lining tanks, drums and chemical equipment is resistant to many corrosive chemicals. Among them are: muriatic acid, any strength; sulphuric acid, 50 per cent and less; caustic soda and caustic potash solutions, any concentration; formaldehyde; bleaching powder; and solutions of practically all metallic salts. The lining can be applied to any shape or size of a container. The equipment can be lined after it is installed. The process of vulcanization does not require any special equipment but can be carried out at any place. It has a tensile strength of over 3,000 lb. per sq.in. It does not crack or check when exposed to light. It remains a tough, pliable substance for many years without any indication of deterioration.

Rubber As A Material in the Chemical Plant

Process of Bonding Rubber to Metal Greatly Extends Field for Both Materials

THE muriatic acid transportation problem, which has always been a source of annoyance to manufacturers and consumers, has been almost completely solved through soft rubber lined tank cars and drums. Distilled water storage and transportation in rubber in which no leakage or pollution results is now quite feasible. Dilute acids such as sulphuric, hydrochloric, hydrobromic, hydrofluoric, phosphoric and sulphurous, can readily be handled and transported in rubber without appreciable affect on the material.

The following table points out some of the chemicals which can be advantageously handled in rubber-lined equipment:

For many years the generally accepted equipment for muriatic acid storage has been the wood tank lined with unvulcanized fine Para rubber. The use of the "Vulcalock" process in attaching vulcanized rubber to the inside of steel tanks not only offers a durable substitute for wood equipment, but also makes it possible to introduce air pressure for discharging the contents. Its advantages might be summarized as follows:

1. Ease of erection.
2. Free from buckling and warping.
3. May be easily moved from place to place without dismantling.
4. Not subject to leakage. The tank may be struck or even dented without injury to lining.
5. Eliminates the necessity of pumps since corrosives may be transported over long distances or to great heights by application of air pressure.

The "Vulcalock" process has also made possible a logical step in the evolution of railroad containers for muriatic acid and other corrosives since vulcanized rubber can be applied to standard design steel tank cars with an adhesion secure enough to easily guard against the rough usage to which the tank car is subjected. About 20 cars have been lined by this process during the past two years with uniformly satisfactory results. The oldest car is still in service with no signs of deterioration.

The steel tank car not only affords the advantage of stability and durability but provides a capacity up to

8,000 gal., whereas the sectional wood tanks heretofore commonly used would seldom provide a capacity of more than 5,500 gal. to the car. The wood tanks have also been objectionable owing to the tendency of the tanks to shift their positions relative to the under-frame, crushing of the staves due to impact of contents, the tendency of staves to expand and contract under different temperatures and humidities and tearing and breaking of the vulcanized rubber linings, due to shock and impact. All of these drawbacks have been eliminated in the steel car.

The Vulcalock bond further re-

sulted in the development of rubber covered sheet metal which is as readily workable as the sheet metal itself in that it can be cut, bent and riveted into many desired shapes. This particular feature is valuable in the construction of flue liners for conducting corrosive acids.

A full line of rubber-lined steel pipe and fittings is now available with either soft or hard rubber lining attached inseparably to the steel by this process. The new process also permits of lining fans and pumps, centrifugal machines, mixers, eggs, lifts, thickeners, classifiers, rolls, vats, bins and agitators.

Resistance of Rubber to Chemicals

	Per Cent Concentration By Weight	Maximum Temp., Degrees F.
Hydrobromic acid.....	Concentrated.....	100
Hydrofluoric acid.....	Concentrated.....	150
Hydrofluosilicic acid.....	Any concentration.....	150
Muriatic acid (hydrochloric).....	Concentrated.....	150
Phosphoric acid.....	Up to 75 per cent.....	125
Sulphuric acid.....	Up to 50 per cent.....	150
Carbonic acid.....	Any concentration.....	150
Pyroligneous acid.....	Any concentration.....	150
Sulphurous acid.....	Any concentration.....	150
Caustic soda and potash.....	Up to saturation.....	150
Calcium chloride.....	Up to saturation.....	150
Calcium hypochlorite.....	Up to saturation.....	100
Copper sulphate.....	Up to saturation.....	150
Sodium acid sulphate.....	Up to saturation.....	150
Milk of lime.....	Any concentration.....	125
Zinc chloride.....	50 per cent.....	100
Aqua ammonia.....	Any concentration.....	125
Ferrous sulphate.....	Saturation.....	150
Sodium chloride.....	Saturation.....	150
Zinc sulphate.....	Saturation.....	150
Aluminum sulphate (alum).....	Saturation.....	150
Acetone.....	.....	130
Ethyl alcohol.....	Any concentration.....	140
Methyl alcohol.....	Any concentration.....	150

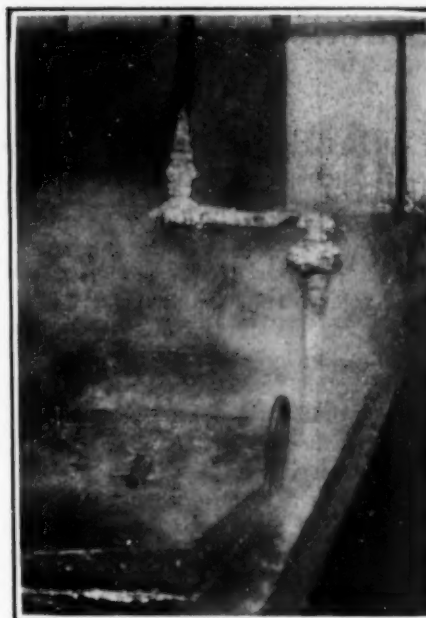


Fig. 2—Heating Weak Sulphuric Acid In A Small Pickling Tank

The upper part of this Duriron circulating steam injector is heavily sulphated, indicative of the corrosive vapors encountered. The Alcumite baskets loaded with small parts are immersed in the bath

pumps of the same material are satisfactorily used, and a specially designed circulating steam injector is largely employed for heating the pickling acids. The physical properties of Duriron, however, eliminate it as a material for the tie rods used on the wooden tanks, the crates, baskets, and hooks.

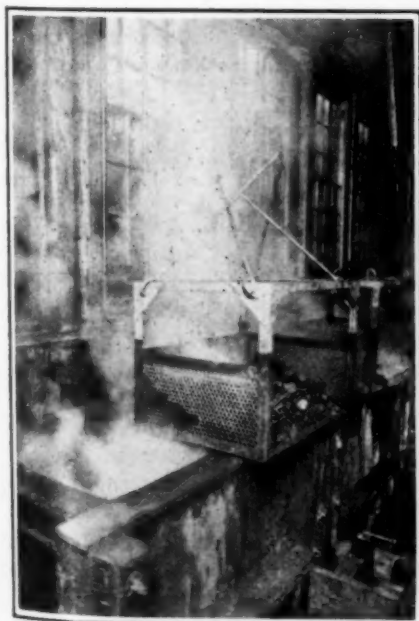


Fig. 1—Pickling Automobile Poppet Valves In The Steel Products Co.'s Plant In Cleveland, Ohio

The baskets shown here are constructed of Alcumite perforated sheet with rods and angles of the same material. These baskets have displaced in this instance much heavier wooden pickling crates which had only one-tenth the life, were of much smaller capacity and required greater use of power and heat

Hot Muriatic and Sulphuric Acids Corrode Pickling Equipment

FEW industrial processes present as severe or as continuous a corrosion problem as is found in the pickling of iron and steel. The principal pickling acids are sulphuric and muriatic or mixtures of the two and these solutions are used at temperatures and concentrations that greatly accelerate their natural corrosive action. The tanks, pumps, pipelines, fittings, valves, etc., used for unloading and storing the fresh acids are of standard construction used throughout the chemical industry. For handling sulphuric acid stronger than 60 deg. Bé. steel pipe and fittings are used and storage tanks may also be made of steel. For muriatic acid, mixed acids and weaker strengths of sulphuric acid, the storage tanks are made of wood—rubber lined in case of the muriatic acid. An acid resisting material, such as Duriron is required for pipes, valves, fittings. Centrifugal



Fig. 3—A Large-Scale Pickling Operation: Immersing Automobile Brake Valves In Hot Pickle Bath

The marked evidences of corrosion of the steel equipment above the tank form a striking contrast with the clean surfaces of the Alcumite rack and the Monel metal chain supporting the rack

Practical Methods of Combating Corrosion in Petroleum Refining

Preventative Measures and Special Materials of Construction Actually Used by the Industry in Solving its Severe Service Problems

IF IT WERE PRACTICAL for the petroleum refiner to substitute for the usual sheet steel at 2 or 3c. per lb. one of the several corrosion-resisting alloys costing 40 to 60c. per lb., it would be possible to fabricate refining equipment that would be relatively corrosion proof. Cost and availability are the determining factors in the search of construction materials that will resist corrosion. In practice the actual solution of the corrosion problems in the oil refinery is usually an economic balance—a compromise between corrosion resistance and the cost of preventative measures and materials. Sometimes it is cheaper to buy steel than to buy and pay for the handling of ammonia, caustic or other neutralizing solutions.

Before reviewing some of the practical operations that are now being applied in the industry in combating corrosion and other conditions of severe service, attention is directed to Table I, which summarizes some of the services of importance in this connection and indicates the special conditions that must be met.

Corrosion of crude-oil still equipment, whether of tube or shell type, is chiefly due to hydrogen chloride and magnesium oxychloride resulting from the hydrolysis under conditions of heat and pressure of such dissolved salts as magnesium and calcium chlorides which are contained in the emulsified water associated with the oil. There is very little corrosion due to hydrogen chloride as long as there is no condensation. Hence practically all of the trouble from this source is encountered in the cooler portions of the system, starting with the vapor line as it enters the condenser and continuing through the condenser.

NEUTRALIZING WITH AMMONIA

The most practical method of handling this problem is by the introduction of ammonia into the system either as a dilute solution in water or by injecting the gas directly into the distillation unit. The amount of ammonia used need not be that which is the full equivalent of the HCl condensed for practical experi-

ence has demonstrated that slightly smaller quantities may be used and yet full protection obtained. This is especially true where aqua ammonia is used instead of the gas and it has an added significance in cases where bronze condensers are employed. An excess of ammonia in such cases has a very deleterious action on the copper in the alloys. If the proper balance between the HCl and the NH_3 is maintained, however, it is often desirable to use brass tubing in several of the first sections of the condenser as a means of cutting down corrosion.

Aqua ammonia used under such

only mildly corrosive to condensing equipment, a refinery in Kansas has obtained satisfactory results by adding a mixture of soda ash and cheap soap solution to the crude oil as it goes to the still. Soda ash seems to work better than caustic soda in that it does not separate as badly, thus forming a cake on the bottom of the still.

Ammonia may also be applied to the neutralization of HCl in cracking operations. A problem of this in the cracking of Smackover crude was solved by injecting a very dilute solution of ammonia into the vapor line just before the oil vapors enter the condenser. No disturbance of cracking conditions was observed by the regular introduction of as much as 50 gal. per hr. of this solution.

CORROSION BY SULPHUR COMPOUNDS

When hydrochloric acid is not present and when the corrosion is due principally to gases and vapors containing sulphur compounds (for

Table I—Severe Service Conditions Encountered in Petroleum Refining

Equipment	Service Conditions
Topping still tubes.....	Sulphide and hydrochloric acid corrosion and oxidation at high temperatures. Erosion from mechanical cleaning.
Plates (bottom of stills).....	Heat, sulphide and acid corrosion, erosion from cleaning.
Still plugs	High temperatures, erosion of hot oil, sulphide and acid corrosion.
Condenser pipes	Hydrochloric acid and salt-water corrosion; dissolved oxygen.
Vapor lines	Sulphide, organic acids and hydrochloric acid.
Bubble trays and caps	Sulphide and organic acids.
Tank roofs and tank bottoms.....	Sulphide and acids.
Gas compression equipment.....	Sulphide corrosion.
Stud bolts	High tensile strength and toughness at high temperatures.
Treating equipment:	
(Tanks, pipes, fittings and valves)	Weak and strong sulphuric acid, organic and sludge acids, caustic solutions. Erosion due to suspended solids.
Pump rods	Acids, sulphides and abrasion.
Valve trims	Acids, sulphides and abrasion.
Wire screens	Abrasion.
Earth revivifying furnace.....	High temperatures and mechanical erosion.
Still and furnace settings.....	High temperatures, sulphur corrosion. Impinging action of hot oil flame.
Burner tips	Excessive temperatures, erosion, sulphur corrosion.
Pyrometer protection tubes.....	High temperatures, erosion and acid and sulphide corrosion.

circumstances serves two additional purposes: (1) Any excess HCl is diluted by the acid and (2) the water flushes out the ammonium chloride which accumulates and may otherwise result in stoppage. When gaseous ammonia is used, periodic flushing with hot water is recommended. As practiced at an Illinois refinery where a Mid-Continent crude containing 0.3 to 0.5 grams of salt (calculated as NaCl) per liter is run, the pipe stills are flushed out every 40 to 60 days. This is done much oftener (after 10 or 15 days) in stills where preheating and counter-current flow are not employed. As much as 50 to 100 lb. of salt may be recovered from a single pipe still unit.

In a case where the crude oil is

the most part hydrogen sulphide) one of the most vulnerable points of attack is in the cracking equipment. It should be understood, however, that corrosion in cracking is solely a function of the charging stock characteristics rather than of the process involved. A heavy stock of high sulphur content will always cause greater corrosion than a light charging stock of low sulphur content.

From the standpoint of corrosion prevention, it is convenient to divide the cracking system into three separate zones. In the first, the cracking chamber itself, the best method of handling corrosion so far known is by lining the chamber with boiler plate or other suitable lining. The purpose of this is to control the cor-

rosion in such a fashion that inexpensive and easily replaceable elements only are subjected to corrosion. Periodic inspection of this lining permits cutting out of partially corroded sections and patching the lining after these sections have been removed. Usually only the upper half of the chamber undergoes any excessive corrosion so that particular attention is paid to the lining of this section.

For convenience in working, 3-in. plate has been found to be satisfactory. The lining material is cut to fit the inner wall of the top head of the chamber, and to extend partially around the side wall. The remainder of the lining on the side walls of the chamber may then be fitted with vertical strips of lining material. The dimensions of these strips are made to conform with the openings of the manhole in the top of the chamber. The lining is usually welded solidly to the inner walls of the chamber, being tacked to the shell by means of welded full holes spaced at various intervals in the plates.

The second zone in the cracking system requiring protection is the dephlegmator leg, hot-oil pumps, and heating tubes. These are preferably protected by the introduction of an alkaline neutralizing agent such as sodium hydroxide which forms stable sulphur compounds. The caustic solution is introduced with the charging oil into the dephlegmator and as the water vaporizes from the solution some of the solid particles of sodium hydroxide remain suspended

in the oil passing in this state to the heating tubes and finally into the reaction chamber where it is deposited with the coke. Protection takes place by neutralizing *in situ* as well as cutting down the amount of corrosive sulphur compounds formed during the cracking process. A small amount of ammonia added to the solution gives protection in some of the cooler portions of the system, but it should be remembered that the ammonium sulphide equilibrium is mainly in the direction of hydrogen sulphide and ammonia at high temperatures.

The third zone of the cracking system, from the protective viewpoint, is the vapor line, the dephlegmator, and condenser. This zone has a decrease in temperature in the direction shown and, except with the vapor line from the reaction chamber to the dephlegmator, undergoes very little corrosion due to sulphur compounds. The vapor line should be periodically inspected to determine its life for various types of charging stocks and certain conditions of cracking, and may be replaced from time to time since it is relatively inexpensive. The chemical solutions may be injected by pump pressure into the system in regulated amounts or by liquid pressure from the special feed containers regulating the amount fed by orifices.

Corrosion problems in connection with acid and alkali treating equipment are no different from those met in the chemical industries handling these materials. In treating oils

continuously using orifice type of mixtures, there is often an acute erosion problem with acid valves and orifice plates.

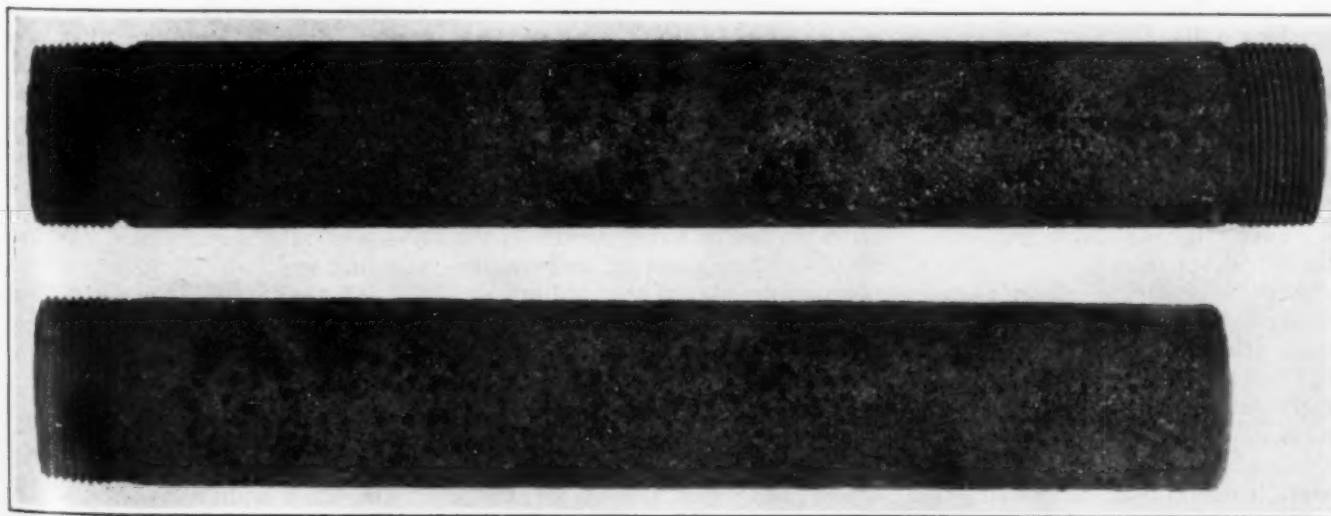
NOTES ON CONSTRUCTION MATERIALS

Special steels and corrosion-resisting alloys are being successfully used on an increasing scale in the petroleum industry. The following notes on a number of old and new materials of construction have had their origin in the reported experiences of various refineries. For the most part they refer to the specific conditions under which they were tested rather than to general applications:

Cast Iron.—Gray cast iron is extensively used in many refineries for bubble tower trays and caps. Cast-iron pipe is resistant to condenser water corrosion and is largely used for this purpose. Closeness of grain is necessary and inclusions of foreign materials should be guarded against. Semi-steel, which is cast iron with increased strength attained by the addition of steel scrap, is used where a cast iron of exceptional strength is needed, as for return bends or preheater tubes in cracking stills.

Copper-bearing Iron and Steel.—While copper-bearing steel plates have proved unsatisfactory for oil-vapor exposure, they have given better results on atmospheric exposure than standard steel plates. Copper-bearing, cast-iron pipes were found by one refiner to give 30 to 50 per cent greater life than ordinary cast iron.

High-Chromium Alloy.—Pyrom-



Accelerated Corrosion of Petroleum Refining Equipment

These 2 pieces of extra heavy steel pipe were removed from a crude oil preheater after 4 months of continuous service. Crude oil passing through this pipe is preheated by the vapors from a crude still and at the same time the heavier constituents of the vapor are condensed and returned to the still. The still temperatures were between 385 and 425 deg. F., and the temperature at the top of the tower was 265 deg. F. Naturally the coldest part of the coil is where the oil enters and the upper piece of pipe with the threads on both ends was the colder of the

two. Onto these threads were screwed an elbow and a coupling. Note how the corrosion was the greatest right next to the fittings which were malleable iron and dropped forged steel in the case of the elbow. Note also the deep pits.

The coil itself shows more even corrosion but had previously been replaced, its life having been about 6 months when the crude oil had been neutralized with the caustic treatment described in the accompanying article. Without this treatment the coil failed in less than a month.

eter protection tubes made of high chromium alloy were found in one instance to be in good condition after ten months of severe service in which steel protection tubes lasted only from four to six months.

Copper-Aluminum-Iron Alloy.—The Stoll Refining Company of Louisville, Ky., experienced severe corrosion in its condensing equipment and finally adopted cast-iron condensers. In a certain connection between the wrought-iron headers and the cast-iron condensers it was found that a steel nipple would last only two weeks in place. Wrought iron nipples lasted three or four months. It was impossible to work a cast iron nipple into this application. As a substitute, a nipple was cast of a copper-aluminum-iron alloy made by the Hills-McCanna Co. and it has been in service for three years without evidence of corrosion. The alloy appears to be as good as cast iron or possibly better for resisting condenser box corrosion. Still plugs and bushings and pyrometer protection wells made of the same alloy have been used in refineries handling Mexican and other high-sulphur crude oils.

Stainless Iron and Steel.—These materials can be used for pump rods, valves, turbine blades, preheater tubes, bottoms of crude stills, gas compression plant equipment, burner tips, condenser tubes and might possibly be fabricated into bubble trays and many other applications. So far cost has been the limiting factor. Hard stainless steel has shown excellent resistance to high temperatures and excessive mechanical wear in cracking units.

Duriron.—Pumps, valves, pipes and in fact all acid and alkali equipment in the treating plant may be made of Duriron. Although highly resistant to corrosion, its physical properties and the difficulty of working have somewhat limited its use in the petroleum refinery.

Metallic Coatings.—Zinc coating, either by galvanizing or by sherardizing (formed by heating base metal in vapors of zinc) is properly used to resist atmospheric corrosion. Aluminum coating by calorizing increases resistance to oxidation at high temperatures. Calorizing has not proved particularly successful in some refineries due to failures of tubes from reasons other than surface oxidation. Lead coating is universally used for acid resistance. Spellerizing, which is a process of mechanically working a metal to

give it a uniform surface, increases resistance to atmospheric and condenser box corrosion. Phosphate coating by the parkerizing process also helps to prevent atmospheric corrosion. Chromium and cadmium plating and the use of the metal spraying processes promise to develop interesting applications in petroleum refining.

Monel Metal.—Still plugs of the forged metal give satisfactory resistance to corrosion and erosion (see p. 621). Bolts made of Monel metal are used in condenser coils and give excellent service. Pump rods for gasoline and sludge pumps made of Monel metal have given better service than steel, but were scored easily due to softness.

The preceding summary represents only the high spots in the varied corrosion experiences of the petroleum refining industry. The information summarized here has been furnished by a number of individuals and plants, and especial acknowledgment is due to the co-operation of Dr. Jacques C. Morrell of the Universal Oil Products Co., Chicago, Ill., W. E. Perdew, General Manager of Refining, Derby Oil Co., Wichita, Kans., and Dr. F. W. L. Tydeman, Supt. of the Roxana Petroleum Corp., Wood River, Ill.

Crystallizing Epsom Salts in Black Iron Pans

Continuous Operation for Two Years Without Trouble from Iron

CRYSTALLIZING magnesium sulphate from its concentrated liquor presents certain difficulties that are not common to all types of chemical production. The work of filling the pans and removing the crystals when formed, which are often matted or tough especially under a sudden change of temperature, requires a material that is hard and not easily injured by an abrasive force. The considerable weight of liquor in large pans requires a metal of high tensile strength or else some sort of buttressing construction. The requirements of ordinary U. S. P. epsom salt are "free from heavy metals" and if an epsom salt of exceptional purity is to be produced the material of the crystallizing pans must not scale, wear or corrode so as to produce contamination.

Wooden tanks cannot be kept tight when handling a growing crystal.



Black Iron Crystallizing Pans For Epsom Salt

A U.S.P. product has been produced in these pans for more than two years without any contamination from dissolved iron salts.

Lead is soft, easily damaged or punctured and will not stand up without a frame, buttress or backing and after a reasonably short usage it is quite evident that the lead of the pans is taken up in some form or other into the product itself, thus becoming a source of the very contamination to be avoided.

Several years ago the Drackett Chemical Co., of Cincinnati, experimented with crystallizing pans of galvanized pure iron and for eight years these pans gave continuous service, which on the whole appeared to be satisfactory. The sheets in the original pans were a little too light to stand the severe treatment accorded them in handling. It was also evident that the galvanizing had gradually disappeared and it was concluded that this had either been taken off mechanically or taken up chemically by the product which was being produced. Although this action was very slow because the galvanizing was still left in part at the end of the 8-year period, it was decided in the next period to avoid even this possibility of contamination.

RESULTS OF TWO YEARS OPERATION WITH IRON PANS

The latest equipment, now in use for over two years, has proved more satisfactory than any of the materials previously tried. The pans were made larger and of heavy Armco iron with welded joints. The strength of material and the weight of the sheets solved the problem of

rough handling. Although it seems strange at first that the crystallizing process could be carried on in a black iron pan without contaminating the product with dissolved iron salts, the point was definitely proved by experiment before the equipment was installed. Constant observation and checking for impurities has developed the fact that none is introduced as a result of the crystallizing process.

Ventilating Equipment to Resist Corrosion

One of the severe corrosive conditions encountered in the plant of the Champion Coated Paper Co., at Hamilton, Ohio, is found in the rosin vats where rosin is saponified with soda ash. The ventilators shown in Fig. 1 are made of 24-gage pure iron, and G. S. Martindale, chief engineer, reports that they are economically resisting the action of the corrosive fumes given off during the cooking process.

Another severe type of service in this plant applies to ventilators which must resist condensed steam from dryers, often laden with chemical fumes from drying paper. The outside of these ventilators are exposed to the usual industrial atmospheric conditions. Over the paper machine itself, conditions are so severe that it is often necessary to replace the rivets because they have rusted away entirely. On the other hand, the galvanized pure iron used on these ventilators was installed in 1913 and is still in excellent condition although unpainted either inside or out.

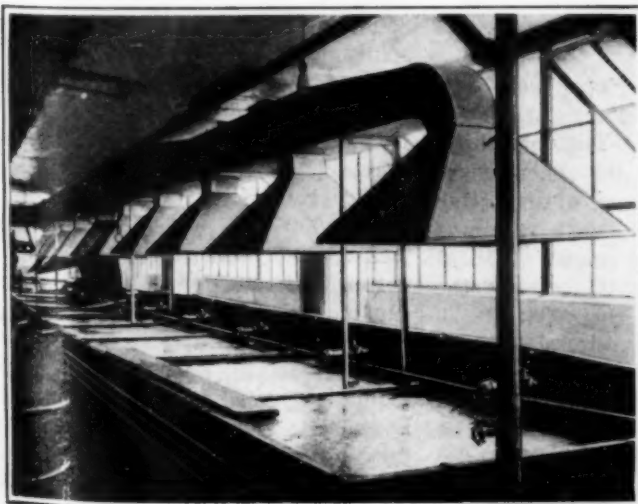


Fig. 1—Pure Iron Ventilators Over the Rosin Size Cooking Vats in a Paper Plant

The iron has been painted with aluminum paint

Concrete as a Chemically Resistant Material of Construction

Fireproofness, Resistance to Wear and Inertness to Many Common Reagents Make Either Plain or Surfaced Concrete Economical

THE use of concrete in facilities at chemical manufacturing plants may be divided into the general headings, the buildings proper, tanks and containers. The methods of design of an ordinary concrete building are more or less a matter of common knowledge, but there are some special properties of particular importance to buildings used for chemical manufacture. Among these are fireproofness, sanitary qualities, resistance to wear and attack from chemicals. If a floor is wet or alternately wet and dry, a material should be chosen which is not affected by these conditions.

FIREPROOFNESS OF CONCRETE

The Underwriters' Laboratories at Chicago have established by tests that the most fire-resistant building materials are reinforced concrete made with limestone or other calcareous aggregate and slag, forming a 2-in. covering over the reinforcing or structural steel embedded in similar concrete with a minimum covering of 4 in. reinforced with wire mesh. It should be noted that tests by this laboratory prove that the aggregate used has a decided bearing on fireproofness. Under intense heat, quartz aggregates have a tendency to spall, while limestone or calcareous aggregate calcines on the surface. Further calcination is retarded by this surface action.

A knowledge of the chemical nature of cement and concrete is of value in a consideration of the effect of chemicals upon it. The hydration of cement results in several compounds, chief among which are calcium hydroxide, hydrated tricalcium aluminate and hydrated calcium silicates. On contact with air, a skin coat of calcium carbonate is formed on the surface of concrete through the action of carbon dioxide on the calcium hydroxide. Most of the aggregates used are siliceous or calcareous, and concrete as a whole is alkaline in reaction.

EFFECT OF QUALITY ON RESISTANCE

Experience has shown that the quality of concrete has a marked influence on its ability to resist severe service. The quality is determined by the degree of care and knowledge used in designing and proportioning the mix, with particular reference to the water content, and in mixing, placing and curing the concrete.

Imperviousness of concrete, perfection of the hydration processes (curing), proportion of the exposed surface made up of aggregate, are all factors which affect the rate of chemical action. It does not always follow that a given chemical reaction involving the compounds in the cement will be harmful—it actually may be beneficial. Thus, if the reaction forms a protective coating,

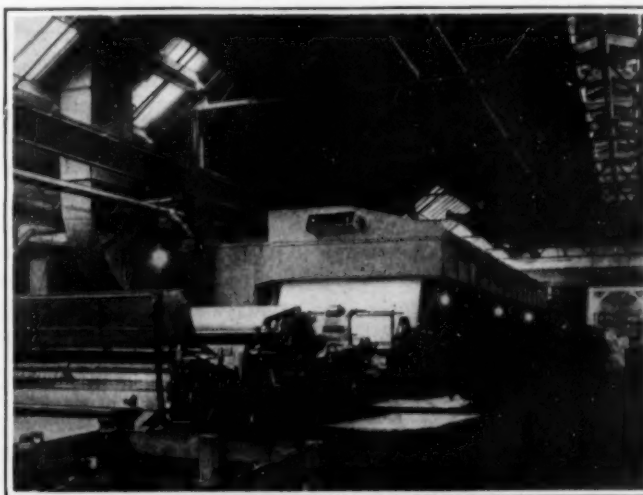


Fig. 2—Drying System Over Machines of the Champion Coated Paper Co., Hamilton, Ohio

These machines blow hot air through the driers

or produces an increase in surface imperviousness, chemical action may cease and the resistance of the concrete may be greatly increased.

No hard and fast rule can be stated as to the chemicals which do not injure well-made concrete. While concrete is not well suited for the storage of liquids containing acids or sulphates in fairly high concentrations, it may be used for almost any other material.

A partial list of substances for which concrete tanks have been used is shown herewith:

Material Contained	Treatment of Container
Crude oil	No treatment in many cases. Sodium silicate, neat cement wash, cement mortar coat, smudging oil, oil-proofing enamel, special varnish and proprietary surface coatings, gunite lining.
Light oil	
Petroleum oil	
Road oil	
Menhaden oil	No treatment
Linseed oil	
Rosin oil	
Sulphite liquor and cider vinegar	Surface coating of 1 part gilsonite, 2.5 parts turpentine, and 5 parts neutral petroleum oil by weight.
Benzine	Surface coating of gelatin and glycerol applied hot.
Salt brine	No treatment.
Molasses	Mostly untreated. Some given inside coating of coal-tar pitch, portland cement and kerosene.
Coconut oil	Bakelite varnish.
Glycerol	Bakelite varnish.*
Cottonseed oil	No treatment.
Soy-bean oil	Sodium silicate.
Fish oil	
Peanut oil	
Ammonia (solution)	Coated with tar.
Bisulphite of lime	No treatment.
Chloride of lime	No treatment if in dry state.
Calcium chloride	No treatment.
Electrolyte	Depends on liquid. Asphalt coating given to tanks, used in electrolytic refining of lead and zinc.
Hydrochloric acid	Acid-proof lining.
Silicate of soda	No treatment.
Sulphuric acid	Fire-brick or acid-proof lining, vitrified tile laid in litharge and glycerol.
Wood pulp	No treatment.
Stock chests	
Zinc chloride	
Hemlock liquors	Brush-coat neat cement or plastered coat cement mortar.
Leaching-bark solution	
Tanning liquors	
Quebracho extract	
Buttermilk	Coats of neat cement grout.
Log boiling	Coated with cement mortar.
Slime settling	No treatment.
Gas purifying boxes	No special treatment.
Caustic soda	No treatment.
Corn sirup	Acid-proof lining.
Glucose	

Tanks required solely for water need no special treatment beyond possibly a coating of rich mortar applied immediately after the forms have been removed. Experience has proved that the same surface finish is sufficient for tanks used for storing crude or other heavy mineral oils, although coatings of a soluble fluosilicate are sometimes used.

VEGETABLE OILS SAPONIFIED ON TANK SURFACE

For the storage of vegetable and animal oils concrete tanks have been in use for many years storing such products as cottonseed, cocoanut, peanut, fish and various other vege-

table or animal oils. Most cottonseed oil companies use no special interior finish. A concern in Seattle, which has tanks of 400,000 gal. for soybean, peanut, fish oil, etc., has treated the interior of the tank with water-glass. A Philadelphia manufacturer uses concrete tanks for storing cocoanut oil and glycerine. While there is some tendency for the lime in the hydrated cement to saponify fatty oils, the resultant insoluble lime soap builds up a protective coating which prevents further attack.

The Hammermill Paper Co., Erie, Pa., has a concrete storage tank for bleaching powder. The bleaching powder reacting on the concrete appears to have formed a protective coating which stops disintegration as long as there are no cracks or abrasions in the material forming the sides of the tank.

Sodium nitrate is stored in concrete tanks by the Eastman Kodak Co., Rochester, N. Y., as a protection from hygroscopic moisture. The Certainteed Products Co., Philadelphia, Pa., uses concrete vats for storing hot potassium hydroxide.

Stephen Sanford and Sons of Amsterdam, N. Y., use a large con-

crete box for steaming yarn after printing. The yarn, which contains some sulphuric acid, remains in the steamer for 20 min. in the presence of live steam at 214 deg. F. and 2 lb. pressure.

TANKS FOR TAN LIQUORS

Tanning establishments have had special problems in the liquor storage. So far as inquiry has been made no serious effects have accompanied the storage of tanning liquors, leaching bark solution and hemlock liquors in concrete. A leather company reports that it has built a tank of 21,000 gal. for containing quebracho extract, finishing the inside of the tank with a plaster coat of 1:2 cement mortar.

The American Locomotive Co., Schenectady, N. Y., has constructed a concrete quenching tank 26 ft. long, 14 ft. wide and 13 ft. deep in its hammer shop. The tank contains a solution made up in proportions of 2 gal. of water, 1 lb. of soda ash, and 1 gal. of heavy mineral oil containing some fatty oils and acids.

CONCRETE VATS FOR BRINE WIDELY USED IN SALT PRODUCTION

Salt companies and other industries that must handle brine in large quantity have been making salt grainers and brine vats of concrete for many years. In these there is frequently a temperature range of more than 220 deg. F. In response to inquiries, executive of plants having installations of this kind seem to agree that salt water is in no way harmful to concrete that has been properly made. Due to salt vapors attacking steel, salt factory buildings are quite frequently built of concrete.

The use of concrete vats for brine solutions naturally leads into the field of food preservation. A meat packing establishment finds such vats do not scale, or get greasy. A vegetable pickling firm in Utah has twenty vats having a total capacity of 120,000 gal., which are used in pickling cucumbers, onions, cauliflower and sauerkraut. No special surface treatment is provided here other than that after a year's use some of the tanks are painted on the inside with hard drying oil paint. A Louisiana refrigerating company uses a tank of 45,000 gal. for freezing ice. In California small concrete tanks are used for pickling olives. They hold a 2 per cent lye solution alternated with brine.

In storing molasses there is a tendency for the material to sour quickly, requiring frequent cleaning of the containers. The better grades of syrup are affected by heat and must be kept at even, moderate temperatures, which prohibit above ground, outdoor storage. Underground concrete tanks for storage have been found to be efficient in molasses storage. In some instance, the tanks are finished without any coating; in others they have been treated with coal-tar pitch, portland cement and kerosene. Steam coils have been placed in the bottom of the tank to keep the molasses more fluid in cold weather.

CONCRETE FOR STOCK CHESTS

In the paper industry, concrete construction is extensively used for stock chests, bleach liquors and calcium chloride solutions. In each of these uses, the inside surface of the tank has not been protected in any way. A fiber company uses concrete tanks to store bisulphite of lime solutions and at other times uses the same vats as containers for chloride of lime; a rubber company stores silicate of soda and several companies have built digesters for boiling wood chips with a sulphuric acid solution. For storing ammoniacal liquors, a St. Louis chemical company lines its concrete vats with a heavy coating of a high-melting tar paint.

CONTAINING ZINC CHLORIDE

An eastern concern was having trouble with containers for zinc chloride, used lead and afterwards copper tanks, both of which were in constant need of repair. Discussing their experience, an official of this company said they "constructed a concrete tank ten years ago against all laws of chemistry and have used this tank constantly without any expense for repairs and it still is as good as the day it was put in."

Protecting Crude Oil Tanks from Lightning

The reason for crude oil tank fires is supposed to be lightning. Indirectly, lightning is the cause of these tank fires, but probably the direct cause is the electrostatic charges on the tank roofs, which are induced by the electrically-charged clouds which pass over tank farms. Many of these wooden roofs consist of wooden decking which is covered

with a tar paper, and a layer of sheet iron which is nailed to the roof. These sheets are insulated from each other very often, due to the fact that where they lap, the edges have been tarred to make the roof gas tight. In some cases the tank roof is insulated from the tank shell. There is an electrostatic charge on these tank roofs during an electrical storm, and when the earth's electrical field is discharged with a stroke of lightning, there is sparking on these tank roofs and some escaping gas is ignited and the tank either explodes or is set on fire. Probably very few tanks are destroyed by a direct stroke of lightning. Practically all the tanks that are destroyed by lightning have wooden roofs, and a steel tank with an all steel welded or riveted roof is ignited only through neglect in leaving gage hatches open or not having the gases properly vented from the tank.

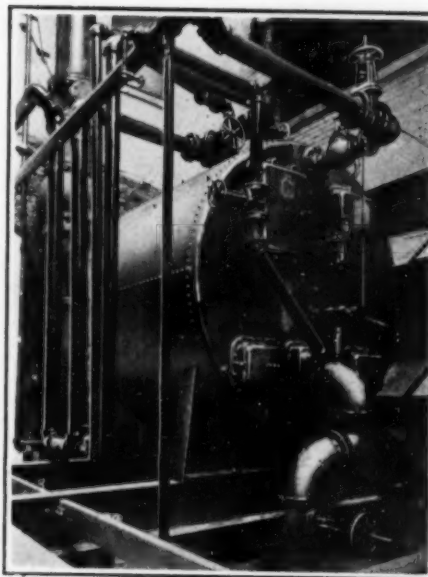


Fig. 1—Feed Water Heater

Fig. 2 illustrates a diversified usage of pure iron in industry. Here we have commercial sifters as pro-



Fig. 2—Pure Iron Sifters for Chemical Plant Work

Resistance of Pure Iron to Chemical Corrosion

Experience of Various Plants Indicates Definite Place for Pure Iron in Structures and Equipment

By D. J. Demorest

Professor of Metallurgy
Ohio State University

These following instances are indicative of severe service where the corrosive conditions are essentially chemical. In studying corrosion as an economic problem, the experiences of actual users of equipment is a phase of study occasionally overlooked, whereas in reality commercial usage is the final criterion as to the real worth of any material.

Dissolved oxygen attack and concentration of salts in feed water heaters make corrosive conditions severe. Fig. 1 portrays such an installation in a New Jersey plant. More than ten years of service has in no way affected efficient performance.

duced in large numbers by an Ohio manufacturer. These sifters are used for all types of service ranging from flour to corrosive chemicals, and yet, to quote from the manufacturer's report—"these sifters are used to handle materials of an abrasive na-

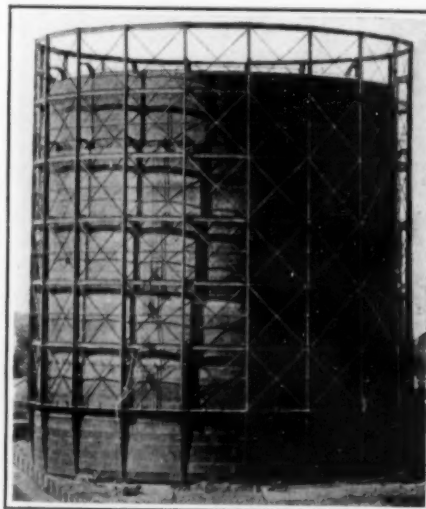


Fig. 3—Gas Holder After 12 Years Service

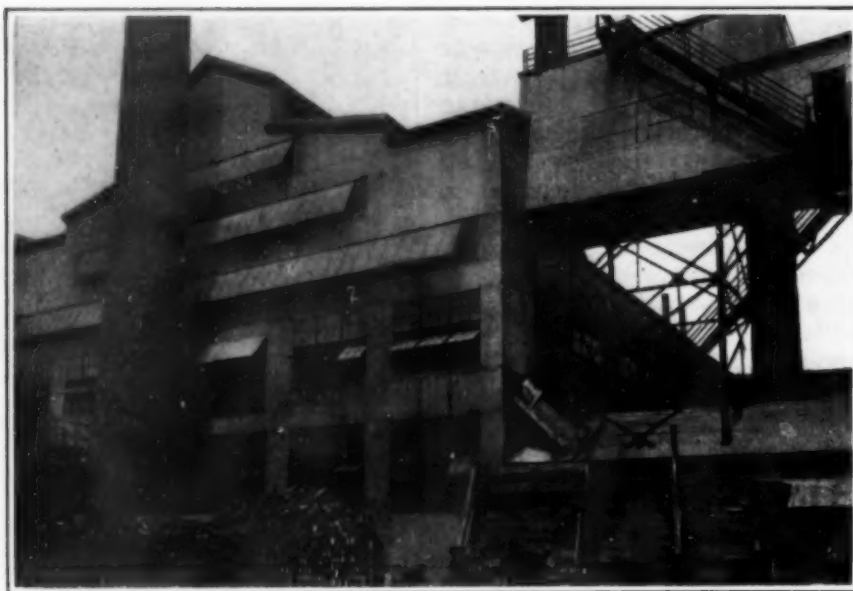


Fig. 5—Iron Siding after Several Years Exposure to Corrosive Atmosphere

ture, others where the sieves run alternately wet and dry, and still others where acids or alkalis tend to produce corrosion, and from observing the results in hundreds of plants, we are more firmly than ever convinced of the all-around usefulness of pure iron."

In Fig. 3 is shown a 5,000,000 cu.ft. pure iron gas holder which is described by the chief engineer in charge as—"it is a good holder, is operating efficiently at the present time, and shows no signs of deterioration whatsoever." This report after twelve years of service.

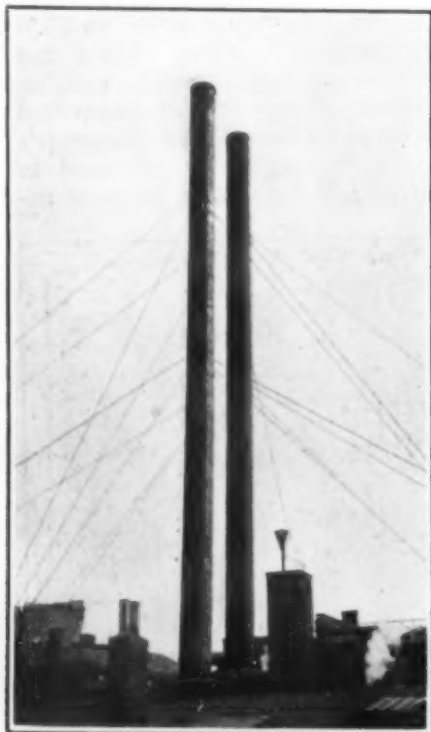


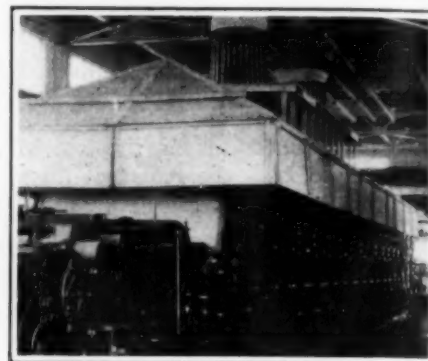
Fig. 4—Pure Iron Stacks

Fig. 4 shows the appearance of the pure iron smoke stacks after over a decade of use for an Ohio chemical company. Although in constant use the engineer in charge reports—"upon recent inspection we are pleased to report that both stacks are in excellent condition, having withstood the severe conditions of acid fumes and soft coal smoke, to which they are subjected, very well."

Paper Machine Hood of Asbestos Wood

To collect and remove the moisture laden air arising from a paper machine is essential if heat is to be conserved and the paper is not to be damaged by rust and dirt particles carried by condensed moisture. A hood of proper design with a careful control of the air supply of the room is standard practice in modern plants. The material of which the hood is constructed should be such that it will not rust or rot nor be in any way affected by the warm moisture arising from the machine. Transite asbestos wood has proved

especially satisfactory for this use because in addition to meeting the above requirements it is fireproof and resistant to acid fumes. On the 75-ton paper machine shown in the accompanying photograph, the hood resulted in a saving of 565 lb. of steam per daily ton of paper, a saving in twenty-four hours of 32.1 per cent.



A Paper Machine Covered With Hood of Asbestos Board

Some Static Duration Tests on Metals and Alloys

Endurance of Annealed Brass, Hard-drawn Brass, Copper and Duralumin

THIS paper shows the time non-ferrous metals and alloys will support a certain constant load in tension. The tests were extended to one year.

In obtaining strength data, care must be taken to approach as nearly as possible actual service conditions. The usual test lasts less than ten minutes. But it is known that the breaking strength of metal decreases if the tensile test is conducted slowly, and therefore the elastic limit in tension has been the criterion governing the dimensions of machine parts for a structure under static load.

Since it is of general interest to know how long a metal or alloy will stand a certain constant over-elastic

Abstracted from *Zeit. f. Metallkunde* (Berlin), p. 75 (1926), by J. Silberstein, material and process engineer, Westinghouse Electric & Manufacturing Co.

Material	Chemical Characteristics	Physical Properties				Duration Load	Broke After
		El. Limit Lbs.	Yield Point per Sq. In.	Ult. Ten. Strength in 2-inch	Elong. Per Cent		
Brass, annealed.....	56.9 Cu 1.7 Pb Bal. Zinc	10,800	22,500	65,400	37	58,000 50,000	8 days *
Brass, hard-drawn.....	56.3 Cu 1.8 Pb Bal. Zinc	24,000	53,000	75,000	14	58,000 50,000 36,000 23,000	1 day 25 days 45 days 110 days
Copper, hard-drawn.....	99.94 per cent Cu	13,000	45,000	48,500	7.5	35,000 29,000	9 mo. *
Aluminum, hard-drawn..	99.5 per cent Al	8,000	14,000	16,700	11.5	14,500 11,600 8,700	3 days 8 mos. *
Duralumin.....	4.5 per cent Cu 0.50 per cent Mg 0.40 per cent Mn	25,500	37,700	63,800	16	58,000 50,700	26 hr. *

load, the following results of tests are given. They were run during one year and may therefore be considered only as preliminary. The physical properties of the different materials were first determined and test specimens then subjected to duration loads. Several specimens of the same material were tested under loads ranging from the elastic limit to the ultimate tensile strength. The results are shown in the table. An asterisk indicates that the specimen did not break within one year.

The results show that the forged brass, despite its higher elastic limit and yield point, did not stand duration load as well as the annealed brass. The hard-drawn brass did not stand a duration stress equal to its elastic limit more than 110 days, although the annealed brass withstood a duration stress equal to its yield stress (and twice the elastic limit of the forged brass) for over one year without failure. Both the hard-drawn copper and the hard-drawn aluminum did not stand duration stresses below their yield point stresses but duralumim (with a yield point of 37,700 lb. per sq.in.) withstood a stress of 50,700 lb. per sq.in. for more than a year without failure.

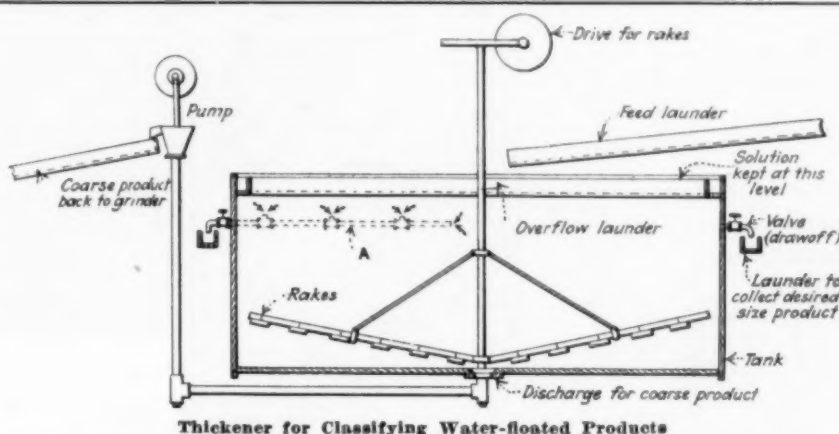
Classifying Water-Floats Products

In a wet-grinding plant producing a fine water-floated china clay, it was required to produce a 200-mesh product from a clay of an entirely different character, using a thickener

24 ft. in diameter and 6 ft. deep. In running the new clay in the same manner as the china clay, it was found impossible to obtain a product of the desired coarseness. The speed of the rakes was increased as high as it was safe to go but did not give the desired result. It was im-

were set so that a small overflow was maintained at the overflow launder at the top of the tank, thus keeping the water level or head at a constant height above these valves.

No difficulty was experienced in obtaining a uniform product after the valves were once set and the feed



possible to allow the pulp in the tank to thicken enough to give the desired product because of sand which also would float over and which was detrimental to the finished product.

Several small holes were bored in the wall of the tank at different elevations and samples were taken at these different points and tested by screening to determine the size of particle. At the elevation giving the 200-mesh product, four 2-in. holes were bored at quarter points around the tank. These holes were fitted with pipe nipples, gate valves and launders to carry away the discharge to the large thickener. These valves

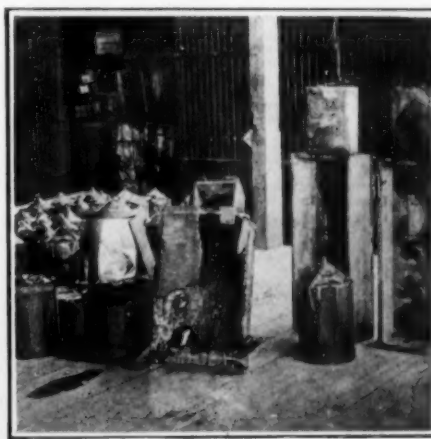
kept reasonably constant. The overflow at the top of the tank could be made to run clear or slimy as desired, by opening or closing the valves. The hydro-separator was made to dehydrate and classify at the same time, thus taking some of the work off the thickener.

By making a greater number of discharge holes in the wall of the tank and carrying in pipes from these points fitted with tees at spaced intervals so that the desired product can be collected over a greater area, the capacity of the equipment can be greatly increased. This arrangement is shown at A.

What Happens When Flammable and Corrosive Chemicals Are Improperly Packed for Transportation



These photographs, supplied by the Bureau of Explosives of the American Railway Association, illustrate the common consequences of the careless packing and shipping of dangerous chemicals. The left-hand picture shows a fire caused by packing concentrated nitric acid in flammable carboy containers.



In the center is to be seen the interior of a steam-heated express car after a disastrous fire caused by storing sheets of pyroxylin plastic in contact with hot steam pipes.

At the right is what happened to a carelessly packed shipment of laboratory supplies containing gasoline and nitric acid.

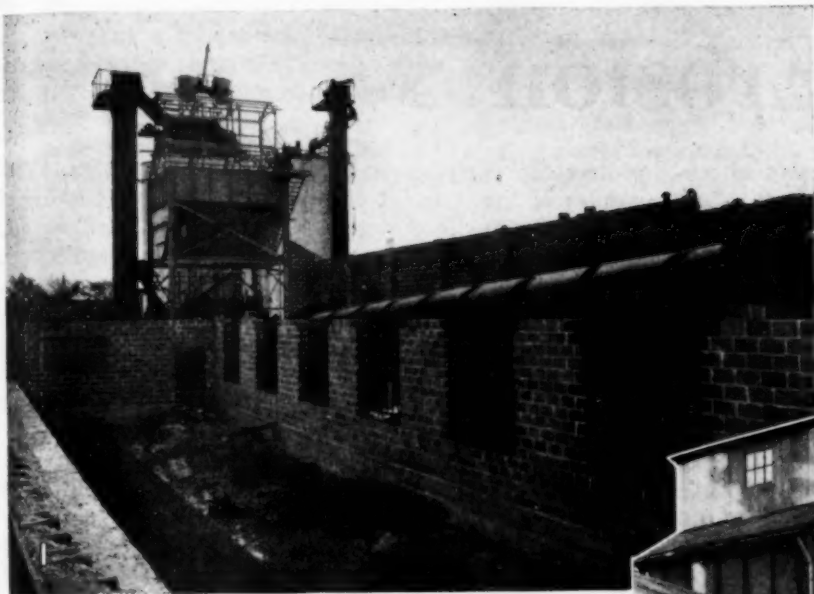
Comparative Resistance of Mild Steel, Chromium Steel, and Chromium-Nickel Steel to Various Media

Reagent	Concentration, Conditions, Etc.	Carbon Steel	12 to 14% Chromium Steel	Chromium-Nickel Steel, Cr 18.0% Ni 8.0%
ACIDS:				
Acetic.....	100%	Attacked	Unaffected	Unaffected
	33%	Attacked	Attacked	Unaffected
	15%	Attacked	Attacked	Unaffected
	5%	Attacked	Attacked	Unaffected
Acetic vapor.....	100%	Attacked	Attacked	Attacked
	33%	Attacked	Attacked	Slight att'k
Benzoic.....	All concns. up to B. P. strength	Attacked	Unaffected	Unaffected
Boric.....	Saturated soln.	Attacked	Unaffected	Unaffected
	50% saturated soln.	Attacked	Unaffected	Unaffected
	5% cold	Attacked	Unaffected	Unaffected
	10% cold	Attacked	Unaffected	Unaffected
	10% hot	Attacked	Unaffected	Unaffected
Carbolic.....	All concns. up to B. P. strength	Attacked	Attacked	Unaffected
Chloroacetic.....	Acid crystals	Attacked	Attacked	Attacked
Chlorosulphonic.....	50% soln.	Attacked	Attacked	Attacked
	Cone.	Attacked	Attacked	Slight att'k
	10%	Attacked	Attacked	Unaffected
Citric.....	All concns.	Attacked	Attacked	Unaffected
Chromic + 10% potassium ferricyanide		Attacked	Very slight staining	Unaffected
Formic.....	Cone.	Attacked	Attacked	Unaffected
	50%	Attacked	Attacked	Unaffected
	25%	Attacked	Attacked	Unaffected
	5% at boiling pt.	Attacked	Attacked	Unaffected
Hydrocyanic.....	All concns., all temps.	Attacked	Attacked	Attacked
Hydrochloric.....		Attacked	Attacked	Attacked
Hydrofluoric.....		Attacked	Attacked	Attacked
Lactic.....	B. P.	Attacked	Attacked	Unaffected
	50%	Attacked	Attacked	Attacked
	50% at 100°C.	Attacked	Attacked	Attacked
Malic.....	25% and 10% at 100°C.	Attacked	Attacked	Unaffected
	5%	Attacked	Attacked	Unaffected
Mixed acids (HNO ₃ + H ₂ SO ₄)	Nitrating mixtures	Attacked	Attacked	Practically unaffected
Nitric acid.....	Sp. gr. 1.42	Unaffected	Unaffected	Unaffected
	Sp. gr. 1.20	Attacked	Unaffected	Unaffected
	Under 11%	Attacked	Attacked	Unaffected
Nitrous.....	Sp. gr. 1.41	Attacked	Slight staining	Unaffected
	5%	Attacked	Unaffected	Unaffected
Oleic.....		Unaffected	Unaffected	Unaffected
Oxalic.....	1% at 15°C.	Attacked	Attacked	Unaffected
	5% and 10% at 50°C.	Attacked	Attacked	Unaffected
Phosphoric.....	100%	Attacked	Slight att'k	Unaffected
	75%	Attacked	Slight att'k	Unaffected
	50%	Attacked	Slight att'k	Unaffected
	25%	Attacked	Slight att'k	Unaffected
	5%	Attacked	Slight att'k	Unaffected
Pieric.....	All concns. up to B. P. strength	Attacked	Unaffected	Unaffected
Pyrogallic.....	All concns. up to B. P. strength	Attacked	Unaffected	Unaffected
Stearic.....		Attacked	Unaffected	Unaffected
Sulphuric.....	All concns.	Attacked	Attacked	Attacked
Sulphurous.....	B. P.	Attacked	Attacked	Unaffected
Tannic.....	5%	Attacked	Unaffected	Unaffected
Tartaric.....	5% at 15°C.	Attacked	Attacked	Unaffected
	10% and 25% at 100°C.	Attacked	Attacked	Unaffected
Acetic anhydride.....	100%	Attacked	Attacked	Unaffected
Acetone.....	100%	Attacked	Slight Corrosion	Unaffected
	50%	Attacked	Unaffected	Unaffected
Alum.....	Saturated soln.	Attacked	Attacked	Unaffected
	50% saturated soln.	Attacked	Attacked	Unaffected
	5%	Attacked	Attacked	Unaffected
Aluminum sulphate.....	10%	Attacked	Attacked	Unaffected
	5%	Attacked	Attacked	Unaffected
	1%	Attacked	Attacked	Unaffected
Ammonium bromide.....	5% at 15°C. and 1% at 50°C.	Attacked	Attacked	Unaffected
Ammonium carbonate.....	Saturated	Unaffected	Unaffected	Unaffected
	10%	Unaffected	Unaffected	Unaffected
Ammonium chloride.....	20%	Attacked	Slight att'k	Unaffected
	10%	Attacked	Slight att'k	Unaffected
	5%	Attacked	Slight att'k	Unaffected
	1%	Attacked	Slight att'k	Unaffected
	47% boiling	Attacked	Attacked	Very slight attack
	23.5% boiling	Attacked	Attacked	Unaffected
Ammonium hydroxide.....	All concns.	Unaffected	Unaffected	Unaffected
Ammonium nitrate.....	10%	Attacked	Unaffected	Unaffected
Ammonium sulphate.....	50%	Attacked	Attacked	Unaffected
	10%	Attacked	Attacked	Unaffected
	5%	Attacked	Attacked	Unaffected
Amm. sulph. + 5% H ₂ SO ₄	At 50°C	Attacked	Attacked	Attacked
Beer.....		Attacked	Unaffected	Unaffected
Benzol.....		Unaffected	Unaffected	Unaffected
Bleaching powder.....	Aqueous suspension	Attacked	Attacked	Slight att'k
Bromine.....	100%	Attacked	Attacked	Attacked

Reagent	Concentration, Conditions, Etc.	Carbon Steel	12 to 14% Chromium Steel	Chromium-Nickel Steel, Cr 18.0% Ni 8.0%
Bromine water.....	3.3%	Attacked	Attacked	Attacked
	1.65%	Attacked	Attacked	Attacked
	0.83%	Attacked	Attacked	Attacked
	0.33%	Attacked	Attacked	Very slight attack
	0.165%	Attacked	Attacked	Unaffected
	0.033%	Attacked	Attacked	Unaffected
Calcium chloride.....	Saturated	Attacked	Unaffected	Unaffected
	70%	Attacked	Unaffected	Unaffected
	50%	Attacked	Unaffected	Unaffected
	30%	Attacked	Slight att'k	Unaffected
	20%	Attacked	Slight att'k	Unaffected
	10%	Attacked	Slight att'k	Unaffected
Calcium hypochlorite.....		Attacked	Unaffected	Unaffected
Camphor.....		Unaffected	Unaffected	Unaffected
Carbon disulphide.....		Attacked	Unaffected	Unaffected
Carbon tetrachloride.....	As purchased	Attacked	Unaffected	Unaffected
	50%	Attacked	Attacked	Attacked
	10%	Attacked	Attacked	Attacked
	1%	Attacked	Attacked	Attacked
Cider.....		Attacked	Unaffected	Unaffected
Chlorine gas.....	Wet and dry	Badly att'k	Badly att'k	Badly att'k
Copal varnish.....		Unaffected	Unaffected	Unaffected
Copper carbonate.....	Saturated in 50% ammonia	Attacked	Unaffected	Unaffected
Copper chloride.....	10%	Attacked	Attacked	Attacked
	5%	Attacked	Attacked	Attacked
Copper sulph. + 2% H ₂ SO ₄	10%	Attacked	Unaffected	Unaffected
Ethyl alcohol.....	100%	Unaffected	Unaffected	Unaffected
Ethyl chloride.....		Unaffected	Unaffected	Unaffected
Ethyl ether.....	100%	Unaffected	Unaffected	Unaffected
Ferric chloride.....	50%	Attacked	Attacked	Attacked
	10%	Attacked	Attacked	Attacked
	5%	Attacked	Attacked	Attacked
Ferric nitrate.....	5%	Attacked	Unaffected	Unaffected
Formaldehyde.....	40%	Attacked	Unaffected	Unaffected
Fruit juices.....		Attacked	Unaffected	Unaffected
Hydrogen peroxide.....	20 vols. at 15°C. at 80°-100°C.	Attacked	Attacked	Slight att'k
Inks.....		Attacked	Unaffected	Unaffected
Iodine.....	1%	Attacked	Attacked	Unaffected
	Saturated soln. + iodine crystals	Attacked	Attacked	Unaffected
Lime and limestone.....	Emulsion	Attacked	Unaffected	Unaffected
Lubricating oils.....		Unaffected	Unaffected	Unaffected
Magnesium carbonate.....	Paste	Slight att'k	Unaffected	Unaffected
Magnesium chloride.....	10%	Attacked	Attacked	Unaffected
Magnesium sulphate.....	10%	Attacked	Attacked	Unaffected
Mercurous nitrate.....	5%	Attacked	Attacked	Unaffected
Mercuric chloride.....	5%	Attacked	Attacked	Unaffected
	2%	Attacked	Attacked	Unaffected
Mercuric cyanide.....	0.5%	Attacked	Attacked	Unaffected
Milk.....	Fresh	Attacked	Unaffected	Unaffected
	Sour	Attacked	Unaffected	Unaffected
Mine water.....		Attacked	Unaffected	Unaffected
Nickel nitrate.....	5%	Attacked	Unaffected	Unaffected
	10%	Attacked	Unaffected	Unaffected
Paraffin.....		Unaffected	Unaffected	Unaffected
Petrol.....		Unaffected	Unaffected	Unaffected
Photographic developers.....		Attacked	Unaffected	Unaffected
Potassium bromide.....	10% at 15°C.	Attacked	Attacked	Unaffected
	5% and 1% at 50°C.	Attacked	Attacked	Unaffected
Potassium cyanide.....	Saturated	Attacked	Unaffected	Unaffected
	50% saturated	Attacked	Unaffected	Unaffected
	5% saturated	Attacked	Unaffected	Unaffected
Potassium ferricyanide.....	Saturated	Attacked	Attacked	Unaffected
	50% saturated	Attacked	Attacked	Unaffected
Potassium nitrate.....	10%	Attacked	Unaffected	Unaffected
Potassium oxalate.....	1%	Attacked	Unaffected	Unaffected
	0.5%	Attacked	Unaffected	Unaffected
	0.25%	Attacked	Unaffected	Unaffected
Sea-water.....	At 15°C.	Attacked	Slight att'k	Unaffected
	At 80°C. in constant agitation	Attacked	Attacked	Unaffected
	Intermittent spray	Attacked	Attacked	Very slightly attacked
Silver nitrate.....	5%	Attacked	Unaffected	Unaffected
	1%	Attacked	Unaffected	Unaffected
Sodium bromide.....	10%	Attacked	Attacked	Unaffected
	5%	Attacked	Attacked	Unaffected
Sodium chloride.....	10%	Attacked	Slight att'k	Unaffected
	5%	Attacked	Slight att'k	Unaffected
	3%	Attacked	Slight att'k	Unaffected
Sodium citrate.....	3.5%	Unaffected	Unaffected	Unaffected
Sodium hydroxide.....	66%	Unaffected	Unaffected	Unaffected
	33%	Unaffected	Unaffected	Unaffected
Sodium hypochlorite.....	5%	Attacked	Unaffected	Unaffected
	0.2%	Attacked	Unaffected	Unaffected
Sodium nitrate.....	5%	Attacked	Unaffected	Unaffected
Sodium peroxide.....	At 80°-100°C.	Attacked	Attacked	Unaffected
Sodium salicylate.....	Saturated	Attacked	Unaffected	Unaffected
	50% saturated	Attacked	Unaffected	Unaffected
	5% saturated	Attacked	Unaffected	Unaffected
Sodium sulphate.....	Saturated	Attacked	Attacked	Unaffected
	10%	Attacked	Attacked	Unaffected
Sodium sulphide.....	10%	Attacked	Unaffected	Unaffected
Sodium thiosulphate + 4% potassium metabisulphite.....	30%	Attacked	Unaffected	Unaffected

Extracted from paper read by Dr. W. H. Hatfield at joint meeting of the Chemical Engineering Group, The British Chemical Plant Manufacturers' Association and the Institute of Metals, at the Congress of Chemists, London, July 20, 1926.

Eliminating Manual Handling in Continuous Manufacture



The manufacture of hydrated lime involves much handling of material. If this work is to be carried out at sufficiently low cost to enable the product to compete, then manual labor must be kept at a minimum. In doing this care must be taken that the costs of the conveying system do not offset the advantages obtained from labor reduction. Hence the best system is that which has the advantage of low first cost, low power consumption, dependability, and minimum manual handling requirements.

Such a system is pictured on this page. Fig. 1 shows the elevators for receiving the raw limestone from the quarry and elevating it to the storage bin, and also the rotary kiln in which the lime is burned. This kiln is heated by producer gas from producers fed by coal delivered at the track hopper in Fig. 2, and elevated to the feeding bin by the elevator.

After the lime is burned it is conveyed to a rotary cooler and thence to the hydrate building shown in



top of the two silos in the foreground. The silos deliver to a feeder which in turn delivers to another elevator which feeds the hydrator. From there a spiral conveyor delivers the material to separators, from which it is blown to collectors, and then distributed by spiral conveyors to the silos shown in Fig. 4.

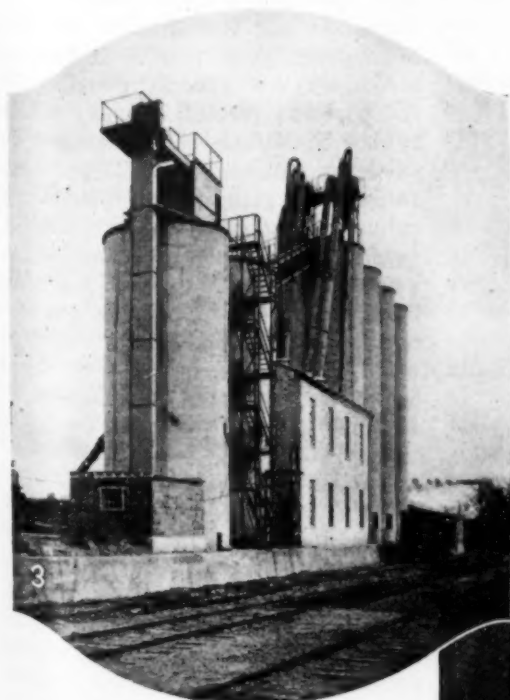


Fig. 3. The elevator in this figure delivers the lime through a spiral conveyor to a vibrating screen on



Erosion

EROSION, the mechanical wearing away of materials, is an ever-present problem in all industries and annually necessitates the expenditure of large sums for the replacement of worn-out equipment. Much of such wear is inescapable, but often the adoption of a different material or design will reduce the wear and thus reduce the maintenance costs.

In the chemical engineering industries the most usual causes of erosion are abrasion due to the abrasive properties of materials being worked, and wear caused by the operation of equipment—principally wear due to rotation in bearings. Most equipment subjected to abrasion must be structurally strong, so that steel or iron should be used as the structural material. A lining of some material, either cheaply and easily replaced or naturally resistant to abrasion, should then be used to

protect the parts exposed to the abrasive action. Examples of this type of construction are found in lined grinding mills, lined chutes and removably-lined pumps. Results of tests on such equipment will be found below.

Protection against undue wear of rotating parts is primarily a matter of design. Good lubrication must be provided. Deleterious substances must be kept out from between moving surfaces. And the design must be such that friction is reduced to a minimum. The attempt to fulfill these conditions has resulted in many highly successful applications of ball and roller bearings. Such applications have not only reduced the wear but have also increased the output and reduced the power consumption of the machines to which they have been applied. More detailed accounts of some of these cases follow.

Rubber Has Helped to Overcome Abrasion In Many Types of Equipment

New Processes for Attaching Rubber for Lining Equipment Handling Abrasive Materials Has Widened Its Application to Industrial Apparatus

RECENT developments, such as the "Vulcalock" process of the B. F. Goodrich Rubber Company, have widely extended the use of rubber in equipment where resistance to abrasion is an important consideration. It has long been known that soft rubber or rubber compounds offer extremely high resistance to wear. For instance, steel skid chains on automobiles travelling over brick or concrete pavement have but a short life, being completely worn out after comparatively limited mileage, while the tires, exposed to the same service, will show no evident signs of wear. Another example of this valuable property of rubber is found in the rubber conveyor belt. Such belts have a wearing surface made up of relatively thin rubber, say $\frac{1}{4}$ to $\frac{1}{2}$ in. in thickness. Yet such a belt will carry millions of tons of abrasive materials such as coke before failure of this thin cover occurs.

In addition to this quality of resisting abrasion, rubber serves as an adequate protection against many different causes of corrosion. Hence we see a growing tendency toward the use of rubber as a lining for chemical engineering equipment, or to protect the moving parts of such machines.

One of the outstanding examples of

such application is the use of rubber linings in grinding mills. An example is a mill in a cement plant, charged with 45,000 lb. of steel balls. This mill is 5x22 ft. and is lined with 1 in. of rubber sheet. After 90 days of continuous operation, inspection showed that the wear on the rubber had been so slight that the cloth imprint on its surface was not yet removed. After 14 months of continuous service, the same lining was inspected and careful measurements indicated that at no place did the wear exceed $\frac{1}{8}$ inch.

Similar tests on grinding mills lined with rubber and handling hard quartz silver ore showed good results. A capacity increase of 15 per cent without increased power consumption and with no sacrifice in fineness of product was realized. In addition a reduced slippage of grinding media against the shell lining was noticed and the consumption of balls was 8.8 per cent less per ton of material ground compared to figures obtained before the rubber lining was installed.

In applying these linings to grinding mills it has been found that dry grinding operations often generate a temperature sufficiently high to cause premature failure. Rubber linings should not be used for dry grinding

where the lining reaches a temperature over 150 deg. F. Also, severe impact will destroy the structure of the rubber and resistance to impact varies in direct proportion to the thickness of the rubber. Therefore, as the size of the individual balls in the grinding charge increases, the thickness of the rubber lining must increase in proportion sufficiently to absorb the impact without a damaging effect.

From tests it is concluded that the rubber lining is best suited to cylindrical mills used in the wet grinding of fine materials, requiring small balls that give a large grinding surface. Among the applications that have given good results is that to secondary wet process grinding in the portland cement industry where rubber lined mills show increases in efficiency ranging up to 20 per cent. In ceramic grinding operations the rubber lining gives good results because it reduces contamination to negligible amounts and the impervious smooth rubber surface permits the mill to be thoroughly cleaned when changes of pigment or other colored material are to be made.

RUBBER IN MIXERS

Rubber is proving valuable in the protection of the wearing parts of mixers and other rotating machinery of similar design. For example, in the mixing of finely ground abrasives such as carborundum, a mixer was used with bronze arms to eliminate undesirable contamination which occurred if iron or steel arms were used. These bronze parts had a life of but 6 weeks and caused much

trouble. As a test, the arms were covered with a $\frac{1}{4}$ in. thick coating of rubber. After 10 months service the coating was still in excellent condition.

Another example of the resistance of rubber to abrasion is given by a test performed on an Ohio River sand dredge. A sheet of rubber placed at the discharge of a 36-in. conveyor received the impact and abrasive action of some 250,000 cu.yd. of sand and gravel during a period of 7 months. This rubber outlasted 10 steel plates of the same thickness in the same service.

A similar use of rubber is found in the lining of sheet metal chutes with rubber, which has proved of great value in prolonging the life of chutes carrying abrasive materials. Also pipe or flues carrying gases contaminated with abrasive dusts

give longer life when made of rubber lined sheet metal.

RUBBER TO REDUCE BEARING WEAR

Rubber lined shaft bearings for rotating machines, such as the "Cutless" bearing, lubricated only with water, have proved to have longer life than metal sleeve bearings when subjected to the action of abrasive materials. For pumps handling liquid containing solid matter, it has been established that such a bearing eliminates wear on either shaft or bearing, provided there is sufficient water flowing over the bearing to properly lubricate it. This is due to the fact that the rubber surface will not permit particles to imbed themselves, but the particles roll to the helical grooves through which the lubricating water flows and are then carried off.

Correct Design and Application of Bearings Reduces Wear

Use of Roller and Ball Bearings Reduces Friction and Makes the Exclusion of Foreign Matter Easier

GOOD bearings are necessary to the economic operation of moving machinery both when the machine is new and during its life. Bearings must be designed to operate with the least possible friction and wear, which means that the design must be good, the lubrication good and the exclusion of dirt, grit or other deleterious matter as nearly complete as can be achieved. Only by the use of bearings that fulfill these requirements can maintenance and power costs be kept low simultaneously with operation at maximum capacity.

These facts are widely realized and, as a result, much work has been done in the application of high-grade bearings to chemical engineering equipment. One of the first fields to benefit by this was the paper and pulp industry, where the maintenance necessary to good operation has been greatly reduced and the output of a given size of machine in some cases doubled. Other wastes have been lessened, incidentally, because of this improvement, which has increased the useful life of wires, felts and machines and reduced power requirements by a large amount.

Examples of such applications are numerous. For instance, the Fitchburg Paper Co., Fitchburg, Mass.,

installed properly designed ball bearings on a 156-in. Fourdrinier machine, on both constant and variable speed shafts, on table and breast rolls, on wire, felt, drier felt and slitter frame rolls and on wire, press, drier and calendar stack drives, a total of 344 ball bearings being used on the machine. Ball bearings on the table and wire carrying rolls of a Fourdrinier machine are shown in Fig. 1. Later, a 110 in. machine in

the same mill was equipped in a similar manner. As a result, maintenance has been decreased greatly. One man is required, on the day shift, to oil and grease the bronze and babbitted bearings on the first machine and keep it clean, most of the time being spent in cleaning. The small ball bearings on the wire and felt rolls and on the table rolls are packed with grease every three months, while the larger bearings on shafts and drives are packed every six months. Lubricating all the ball bearings on the machine requires but 48 man-hours of work. The use of these bearings saves 6 quarts of oil per day and the continuous attendance of one man. Replacements are greatly reduced, only about 5 a year being now required, as against one daily. The life of machine wires has been increased from 16 to 21 days. About 25 per cent of the power requirement is saved. Altogether, the saving in lubrication, maintenance, wires and power amounts to between \$9,900 and \$10,000 annually.

The Robert Gair Co., Montville, Conn., replaced a former bearing installation on the couch rolls and cylinder molds of two paper machines with self-aligning ball bearings. After 3 years of almost continuous service, without any repairs, these bearings were still in good condition. The machines make boxboard from 0.014 to 0.045 in. thick and run at speeds ranging from 30 to 220 ft. per minute. The cylinder mold shafts are $4\frac{1}{2}$ in. in diameter and run at a maximum speed of 23.3 r.p.m. The use of the ball bearings

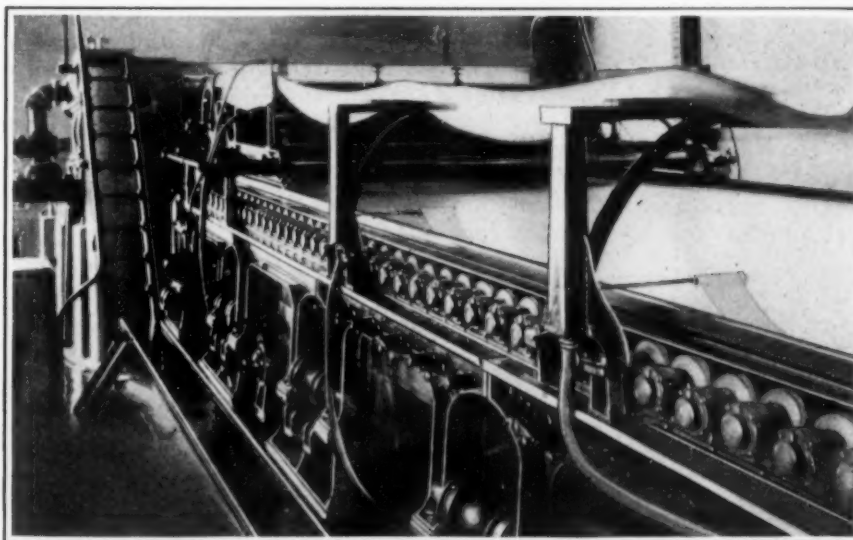


Fig. 1—Application of Ball Bearings to a Fourdrinier Machine

This view shows particularly the bearings of the brass table and wire carrying rolls. Other ball bearing equipped rolls and drives are not shown because of the great length of the machine.

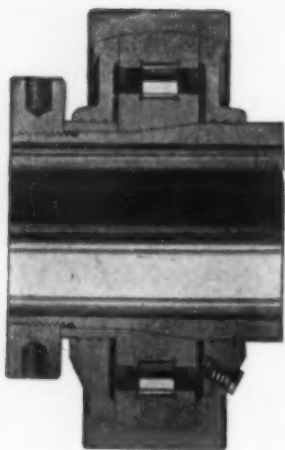


Fig. 2—Moisture-Proof Bearing
For machines, such as those used in the manufacture of paper subjected to very wet operating conditions, bearings such as this have given good results.

has permitted a speed increase from 120 to 220 ft. per minute. With an increased production per felt of 22 per cent, the life of the felt, about 3 weeks, has not been reduced. The saving in wire cost per ton of paper is about 15 per cent. Saving in cost of lubricant is about 25 per cent and in labor of lubrication about 22 per cent. The total annual money saving for the two machines is nearly \$4,000.

KEEPING MOISTURE OUT OF BEARINGS

A good bearing must be designed to keep out grit, moisture and other foreign substances. One of the most difficult applications of this nature occurs on paper machines and other machines where large quantities of moisture are present. There are four requirements that must be met on such applications: (1) Due to the length between bearings and the fact that each bearing must be mounted in a separate casing, it is impossible to align the two housings, so that the bearings must be self-aligning. (2) The bearings must be protected against the entrance of moisture or corrosion will occur. (3) Provision must be made for expansion or con-

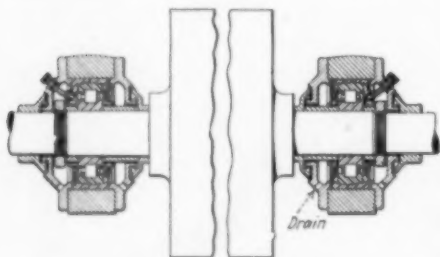


Fig. 3—Moisture-Proof Bearing Applied to Paper Machine
In this bearing, cover plates and slingers are provided to afford additional protection to that given by the swivelling cover plates.

traction of the rolls during changes in temperature or the bearing will bind. (4) Means must be afforded for lubrication at an easily accessible point.

To fulfill these conditions, a bearing of the type shown in Fig. 2 has been found suitable. It has an outer spherical shell in which the bearing proper is seated. The swivelling side cover plates are ground to fit this outer shell so that a very close clearance may be maintained at all times between the bores of these cover plates and the rotating shaft. An application of a bearing of this type on the breast and wire rolls of a Fourdrinier paper machine is shown in Fig. 3. Here stationary cover plates and slingers are pro-

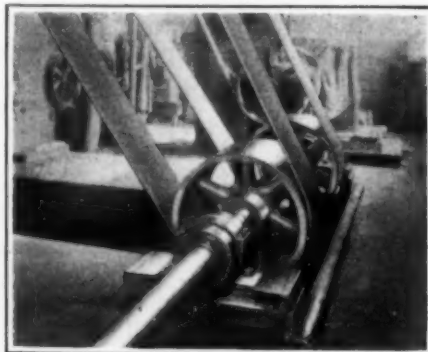


Fig. 4—Bearings on a Beating Engine Drive
The use of the bearings shown here relieved an overloaded motor and made unnecessary the installation of a new and more powerful motor.

vided to offer additional protection to that of the swivelling cover plates. The running clearances between these rotating and stationary parts must not be too close or binding will occur when the parts are out of alignment. Any moisture passing the other cover plates is drained out through the bottom of the housing, but can penetrate the bearing no further. A flexible tube, shown in Fig. 3, permits grease under pressure to be forced directly into the moving parts of the bearing. Expansion is taken care of by allowing one bearing to be clamped endwise by means of the flanges on the cover plates while the other bearing is free to float endwise as needed.

BEARINGS FOR HEAVY DRIVES

Ball bearing pillow blocks used for beating engine drives by the Keith Paper Co., Turners Falls, Mass., give an instance of a successful bearing for a service condition. Fig. 4 shows one of these bearings. Two $4\frac{1}{2}$ in. diameter shafts, each driving 3

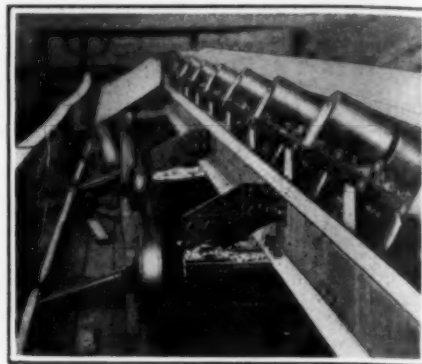


Fig. 5—Ball Bearing Shuttle Conveyor
This conveyor operates in a dusty place and it formerly required the aid of a crane to move it. Since the wheels have been equipped with ball bearings it is easily moved to any location desired.

1,000 lb. beating engines, are each directly connected to driving motors. The company was faced with the necessity of installing more powerful motors if the required work was to be done by the beaters. Instead the old bearings were replaced by ball bearing pillow blocks and the friction load was so reduced that the original motors were able to do the work. Also, a reduction in lubrication and maintenance cost was obtained.

BEARINGS FOR CEMENT EQUIPMENT

Conditions in cement plants are such that bearings on cranes, conveyors, motors and other moving equipment are exposed to abrasive dusts and heat. For this reason, much bearing trouble has been experienced in these plants. But installations of ball bearings, such as those made at the plants of the New Egyptian Portland Cement Co. have given satisfactory service and seem to have overcome the difficulties.

Fig. 5 shows a shuttle conveyor operating back and forth over storage. When equipped with plain bearings in its traveling wheels, it would become struck, due to dust

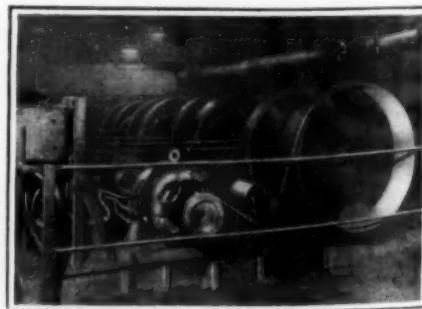


Fig. 6—Air Compressors in a Cement Plant
The idler pulleys on this installation of air compressors are now equipped with ball bearings which have given good service for over two years.

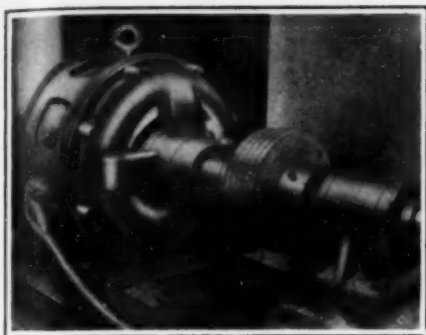


Fig. 7—Ball Bearings for Cement Plant Drives

The extremely dusty conditions which necessitate the use of high-grade bearings in cement plant work are evident from this view.

settling in the bearings; but since ball bearings have been installed on these wheels, the shuttle can be easily moved to any desired location.

Fig. 6 shows the same company's air compressor installation at one of its plants. The idler pulleys formerly gave much trouble, the bearings becoming worn out and needing replacement in about 3 months. These pulleys are now equipped with ball bearings which have given over 2 years' service and are still in good condition.

Another example from cement plant practice is shown in Fig. 7, where the main shaft bearings of direct-connected motor drives are now ball bearing units. The result is a useful life of over a year compared with but 6 weeks for the former type of bearing. The extremely dusty conditions under which the bearings operate is evident from the picture.

Dredge Pumps for Handling Abrasive Materials

Pumps are often required to handle mixtures, slurries or pulps of an abrasive nature. If this is done with the usual type of pumps much trouble is experienced from undue wear, causing shutdowns for repairs. However, steel-lined pumps with renewable liners of the type used for dredging or pumping sand have been used in such cases with much success.

One example of such practice is found at the Pacific Portland Cement Co., Redwood City, Calif., where cement slurry is raised from the raw slurry tanks to an elevation of about 30 ft. Air was first tried for handling this slurry but was not successful. Later, a large plunger pump was tried but gave trouble through undue wear. Finally, a 4-in. square casing, steel-lined dredge pump was

used. This latter pump solved the problem, and handles approximately 200 gal. per minute against a 35-lb. pressure of slurry containing 60 per cent abrasive solids by weight.

Another problem of this nature was solved at the Mason By-Products Co., Sausalito, Calif., where pulped raisins are pumped through 200 ft. of pipe and elevated about 20 ft. This pulp, taken directly from the grinder, is charged with air so that it cannot be handled by the ordinary centrifugal pump. In addition the pulp contains large amounts of sand, pebbles, tramp iron and other foreign matter, so that its abrasive action on the ordinary pump was high. A steel-lined, sand pump was installed and has stood up under the conditions for over 18 months, at the same time not becoming air-bound as the centrifugal pump did.

Grinding Problem Solved By Ball Mill

Grinding alundum is about as severe a service as any to which a grinding mill could be put. At the Pittsburgh Plate Glass Co., Ford City, Pa., where this material is wet ground to a fine powder for polishing plate glass, the maintenance cost of the grinding equipment had been very high. Also, with the mills used the power consumption was high and the capacity low, so that the total grinding cost was high.

In January, 1922, this company installed a 5 ft. x 22 in. Hardinge ball mill, to operate in a closed circuit with a Dorr bowl classifier and later another classifier and a thickener were installed. Since that time the mill has operated continuously, producing as much as several of the old mills with much lower repair costs. Outside of the addition of new steel balls to keep the charge in the mill at a constant level and the replacement of one set of liners,

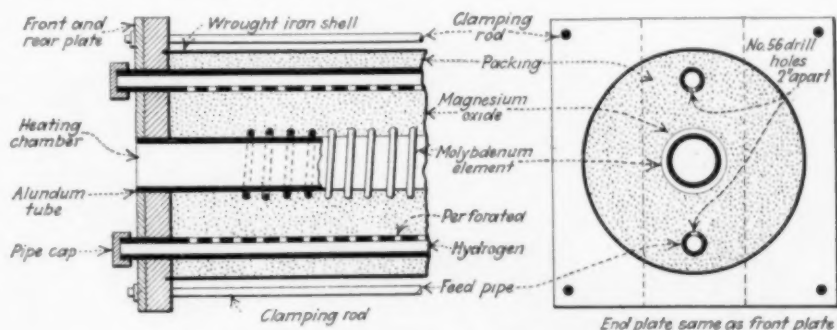
there have been no shutdowns for repair. This instance of good service has resulted in the adoption of similar equipment for grinding alundum by a number of other plate glass manufacturers.

Resistor Tubes for Small Furnaces

Severe service conditions are experienced in electric furnaces for wire drawing, especially in those plants where incandescent lamp filaments are produced. Consequently the parts going into these furnaces should be able to stand up in order to prevent frequent shut downs. The length of the furnace life is dependent upon the tube which supports the resistor.

Temperatures up to 1,700 deg. C. may be obtained by using a molybdenum-wound furnace such as is illustrated in the accompanying sketch. The melting point of molybdenum is around 2,500 deg. C., and with a suitable refractory high temperatures can be reached. Of course, there is always the danger of oxidation of the molybdenum wire and for this reason an atmosphere of hydrogen must be present always to prevent oxidation. The refractory supporting the resistor wires must be sufficiently porous to permit hydrogen gas to pass through the tube wall. At the same time it must resist conducting electricity, must conduct heat rapidly and at the same time be able to resist high temperatures.

Alundum tubes are giving good satisfaction in many nationally known plants where this type of furnace is employed. They are made of a high percentage of electrically fused alumina bonded with carefully selected refractory clays. Tubes of this type have been reported as giving service of two months or over under continuous operating conditions.



Longitudinal and Transverse Section Through Furnace

Molybdenum Wound Wire Drawing Furnace

Alundum tubes for supporting the metallic resistors have been found satisfactory in this type of furnace at 1700 deg. C.



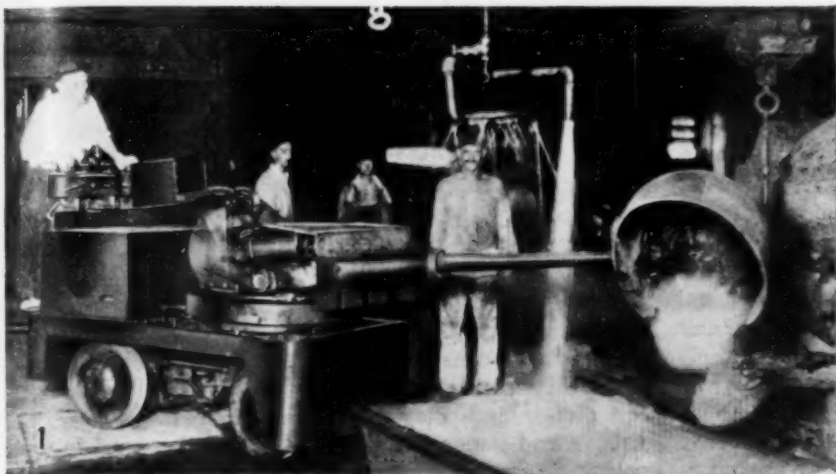
Storage Battery Trucks and Tractors Solve Many Package Handling Problems

Material handling equipment used in the chemical engineering industries is everywhere subject to the same conditions of severe service that are imposed upon straight process apparatus. The incentive to lower costs of moving material or stock through successive process steps is none the less definite, however, on this account. The present-day urge to evolve increased economies in production costs, either direct or indirect, demands that this business of material handling be subject to the same attentive scrutiny that the business of conducting process operations receives.

On this page there are four suggestions drawn from the present practice of concerns in the process field that have been pressing forward toward lower costs—suggestions capable of adoption in the same or in modified form in many plants that still employ manual equipment for carrying out many of their handling operations to the exclusion of power operated devices.

Barrels, bags, carboys and the strapped skid are representative packages containing products of the process industries. The loaded skid, upper left, containing 2 tons of paper, is placed as shown in the freight car for shipment—making possible a saving of 30 to 40 man-hours in loading and again in unloading each car. The tractor-trailer method, upper right, illustrated as used in a packing plant, has led to the development of elevators shown in the background that carry the fully loaded train without breaking up. The high lift truck, lower right, tiering bagged material, utilizes floor space while multiplying the driver's capacity 8 to 10 times. Finally the use of the same equipment for moving carboys, shown lower left, carrying from 5 to 10 times the load of a hand truck at several times his walking speed, is a practical method free from hazard and frequently offering an opportunity for cutting the cost of handling by 50 per cent.





Special Bodies Adapt Trucks To Interprocess Handling

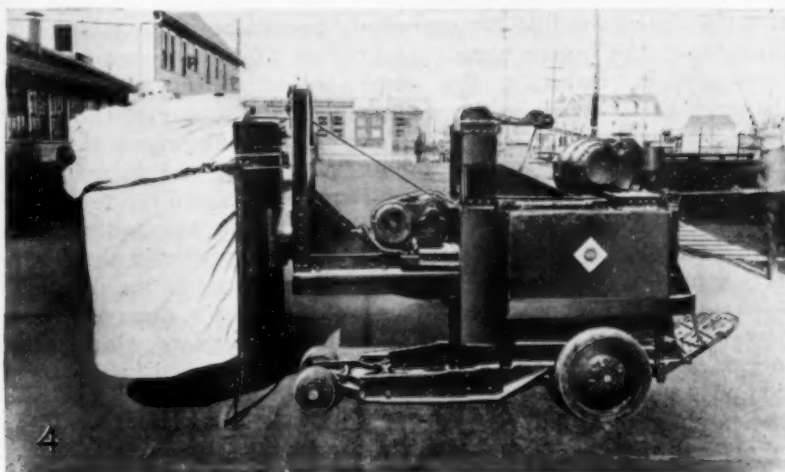
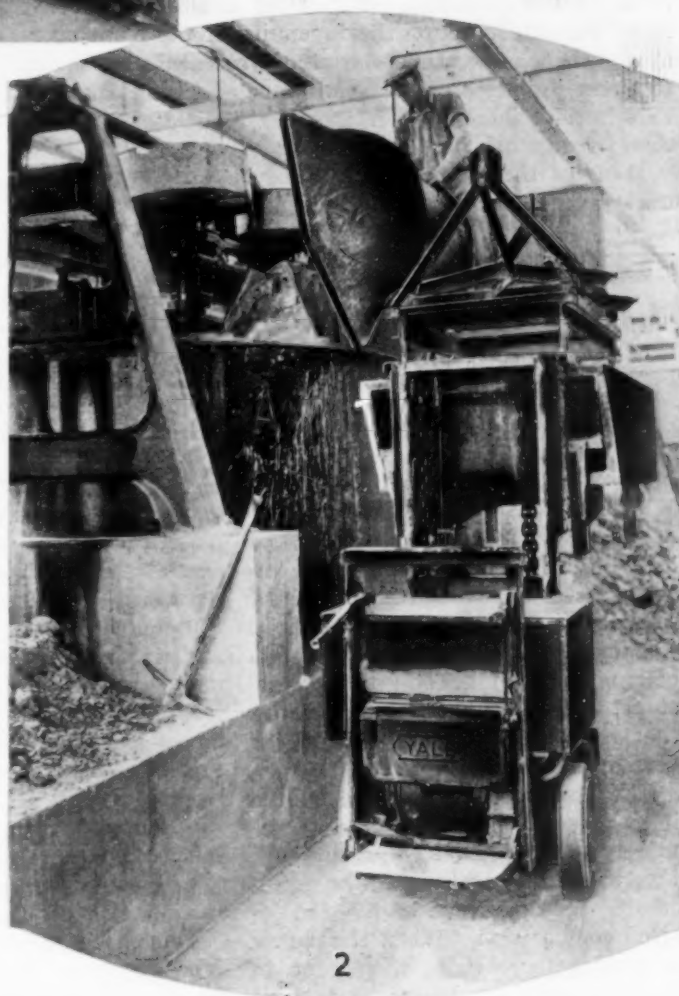
Although the electric industrial truck is only one of several types of power operated equipment that may be used, its mobility, wide range of utility and low operating cost, seldom exceeding 50 cents per hour of service, have increased the favor with which this equipment is regarded as a means for lowering interprocess handling costs under severe service conditions. The use of special bodies, or skids of special type permits the application of these trucks to interprocess work, giving speedy movement of material and at the same time aiding in the synchronizing of operations.

Glass, for instance, has to be speeded from melting furnaces to drawing kilns. The truck shown in Fig. 1 was designed to make a saving of \$31,000 a year in this transfer. At the same plant the platform truck is used for moving heavy, fragile cut plate from finishing to packing.

Fig. 2 was taken in the plant of the West Coast Porcelain Co., which was laid out with the idea of minimizing material handling costs. A specially designed skid platform equipped with dump body and automatic scales enables the operator to weigh accurately every charge, subdividing according to formula, and to transport, elevate and dump without assistance.

Bulk handling is necessarily practiced on a large scale where solids are transported dry. The skid carried by the lift truck shown in Fig. 3 is one of the many devices adopted to tie the flexible "on the ground" system to fixed overhead equipment such as cranes, tramrails and hoists—the rings bolted to the skid frame provide for rapid transfer.

Increasing pressure to devise handling economies is reflected in highly refined types of equipment, modified for particular operations. The truck in Fig. 4 represents a recent type for the rubber industry for handling rolls of calendered fabric without the injury that may arise through the application of pressure.



Unusual Plant Conditions

UNUSUAL operating conditions are the order of the day in many, if not most, of the chemical engineering industries. No better evidence of this fact is available than in the preceding discussion of the wide variety of unusual problems that can be conveniently grouped under such broad headings as—Corrosion and Erosion, High Temperatures and Pressures, Safety and Explosion Hazards.

But there are equally as many problems that cannot be as readily classified, yet they are often the ones that lay the greatest tax on the ingenuity of the plant operator. There is no accumulation of precedents applicable to these problems. The solution must come from the case in trial and the experience thus gained is often the costly result of long experiment.

Many of these unusual problems have to do with the unit processes and the equipment by which they are

applied. In the pages that follow, specific instances are recorded of difficult operating problems in the mixing, grinding and drying of materials. Many other examples could be adduced were space available for their presentation.

Unusual operating problems often call for unusual materials of construction. Much of the preceding discussion has centered around corrosion- and heat-resisting metals and alloys. Of the non-metallic materials, rubber and cement have already been discussed in their relation to corrosion and erosion. It remains for the present section to treat of such unusual materials of construction as the phenol resins, pyroxylin plastics, fused silica and quartz, and sulphur-impregnated wood and concrete—newer products that are finding many important applications in solving unusual operating problems in the chemical engineering industries.

Combined Air and Mechanical Agitation Solves Unusual Mixing Problem

Absolute Homogeneity Must Be Maintained in Mixing Cement Slurry During Wet Manufacturing Process

IN THE MANUFACTURE of Portland cement by the wet process, a difficult problem in agitation is encountered. The constituents of the cement are first brought together in the form of a slurry which consists of a mixture of finely ground limestone, finely ground marl and water, the latter being about 33 to 40 per cent of the total weight.

The constituents are first placed in a correction basin in approximately the required proportions, then samples are taken and the necessary corrections made to give the desired composition. When the slurry is satisfactory, it is then sent to storage agitators where it is kept under constant agitation with a view of maintaining absolute homogeneity throughout the entire mass. It is necessary to maintain the same thorough agitation while the storage basin or slurry mixer is being filled and while it is being emptied. This presents an exceptionally difficult mixing problem to handle mechanically because of the fluctuation in pulp depth in the mixer.

Three general types of agitators have been used, i.e., mechanical agitation, air agitation and a combination of mechanical and air agitation. The mechanical agitators consume a great deal of power, and while they

give excellent mixing in a horizontal plane, they do not cause an appreciable circulation vertically which results in the slurry becoming stratified and, therefore, not homogeneous. Air agitation alone does not prevent the coarser particles of material from collecting on the bottom of the mixer at points where the air jets are not effective. Also it is expensive to operate. A combined mechanical and air agitation process developed by the Dorr Co., overcomes the objections above, in that it insures homogeneity at a low cost.

This machine consists of a set of rotating arms to which plows are attached, driven from a central shaft and rotating in a plane parallel to the bottom of the mixer. The function of these rakes is to scour the bottom of the tank and sweep any settled coarse material to the center of the tank where it can be again picked up and mixed through the mass. Around the vertical shaft and resting on the rakes is a cylinder extending upward about one-third of the distance to the maximum slurry line. On the arms are a number of short cylinders which are likewise rigidly attached to the arms and rotating with them. A group of compressed air pipes are brought down the central shaft, one being attached

to each cylinder. The central cylinder acts as an air lift which raises the settled solids that are brought in by the plows up into the upper strata of the tank, the small cylinders act simply as air jets to increase the agitation between the center and periphery of the tank, and they are effective due to the fact that they are continually moving.

Unusual Service for Pyroxylin Lacquer

In a vulcanizer used in one of the manufacturing processes of the Joseph Stokes Rubber Co., Ltd., at Welland, Ontario, a severe corrosion problem was encountered on the interior surfaces of this equipment. Formerly a paint made of red lead and boiled linseed oil was used, but in spite of the fact that applications were made every two weeks, the corrosion persisted. Apparently the paint film was broken by the alternate expansion and contraction of the vulcanizer metal during the curing operations. The maximum temperature reached on the interior of the vulcanizer was 324 deg. F.

It was suggested that a pyroxylin lacquer might be suitable for this service and accordingly a heavy coat of dark gray Duco was applied with a brush. The film thus produced proved to have unusual resistance to the peculiar conditions encountered in the vulcanizer and this treatment has since been adopted as standard in the Canadian plant.

Severe Service for Dryers

Description of Unusual Installations Designed to Meet Peculiar Drying Problems in Chemical Engineering Industries

THE FACT is well established that rotary dryers are among the least attended, most abused and regularly used pieces of equipment in many industries of today. Because of these conditions inefficient operation is seen on every hand. However, a number of such conditions can be traced to the lack of thought given to the proper design of the dryer to meet the severe service for which it is intended and to the common malpractice of purchasers in selecting equipment that shows the lowest pound price rather than that which has behind it the thought of experienced engineers and the workmanship of trained mechanics. This is as true of what may be termed the ordinary single shell dryers, as it is of the more modern double shell dryers for both direct and indirect heating.

At the plant of the Nazareth Cement Co., in Nazareth, Pa., two specially designed single shell dryers are installed to handle limestone that is crushed to pass a 3-in. ring and to dry the stone to less than one per cent of moisture under all conditions. Cement plant practice calls for 24-hour operation, although there is sufficient leeway in capacity that both dryers are not necessarily called upon for this continuous service. They were installed for 50 tons per hour, while each one has been run at times for as high as 60 tons per hour. These dryers are ruggedly built throughout, but the outstanding features of design are, removable steel plate liners extending the entire length of the shell, a feed head of plate construction with machine finished sealing rings and a cyclone dust collector set to discharge directly into the dry stone elevators. This design affords the operator assurance of short delays for repairs, allows for maximum shell length in minimum overall dryer length and a positive handling of the dust. The service in this case is severe because of the large size of the stone fed to the dryer and the great amount of fine dust that is handled; about 15 per cent of the stone dried.

The National Carbon Co., has in operation at its Philadelphia plant

a plate-steel lined dryer with cast-iron flights of somewhat the same arrangement as in the preceding instance, although smaller since used for drying manganese ore. This ore comes in under all conditions of weather and is very hard and abrasive. Even then the ore is crushed to $\frac{1}{2}$ -inch the service is severe. The lining of the shell is the solution to the problem of delays for repairs that otherwise seriously affect operating schedules.

PREVENTING CONTAMINATION

If strict requirements as to finished product can be considered as severe service, then the refractory lined single shell dryer used by the Crane Enamelware Co., at Chattanooga, Tenn., is a good example of how provision can be made to assure the operator of desired results. In this case, as also in the case of dryers used for drying feldspar, the product must be free from contamination due to contact with iron. The material handled by the Crane company is a high-grade enamel frit which after drying is pulverized and coated on sanitary ware before baking to give a smooth, spotless, glossy surface. After coming from the quenching pits the highly abrasive frit, in pieces of one inch or less, is fed to the dryer and dried to a bone-dry product. As is the case of all drying operations, agitation of the material while passing the heated air through it, effects the most economical drying. This is accomplished in this type by a special arrangement of the lining so that the frit is properly cascaded in the shell. Further assurance of freedom from contamination is obtained by the use of waste heat from the melting furnace being passed through recuperators which supply the necessary heat for the dryer.

Freedom from contamination is a requirement in other industries such as the clay plants producing for the rubber and paper trades. Where gases from the furnace are a source of contamination, indirect heat for drying must be employed. There are a number of dryers of this character operating satisfactorily in the Langley (S. C.) kaolin fields, at Mac

Intyre, Ga., Cold Spring, Va., and other places.

A more than usually severe service on dryers of this type is evident at the plant of the West Virginia Pulp and Paper Co., at Tyrone, Pa. The material is leacher refuse which, when dried, is in the form of small granules of very light weight and readily subject to combustion. While containing as much as 6 per cent moisture, after drying from the original moisture of about 68 per cent, the material from all indications is bone dry. These are conditions of operation that call for special features of design. Some of the very fine material readily ignites and when this occurs the strains in the shell due to the sudden rise and fall of temperature, must be provided for, as all parts of the shell are not heated to the same degree at the same time. These dryers are the double shell indirect heat type and have proved mechanically satisfactory at all times.

AVOIDING FLAME CONTACT

While it is possible to use a steel-plate lined single-shell dryer on silica sand similar to the dryer previously described for manganese ore, many producers of high-grade sands require that contamination from direct contact of the furnace flame be reduced to a minimum. With the use of the double shell semi-direct dryer the sand is handled in a better way, as the flame does not play directly on the material. However, it is necessary to employ special features of design to take care of the wear due to the abrasive nature of this material. At the plant of the Pioneer Silica Products Co., at St. Louis, a dryer of this type has been in operation for some time and no mechanical troubles are evident.

Mechanical difficulties of the same character as those experienced when drying leacher refuse and anthracite culm are also met in drying wood chips containing fines. An accurate control of temperature is necessary although the dryer must be capable of withstanding the sudden changes in expansion and contraction in the event of improper control. In handling hard wood chips, the Tennessee Eastman Corporation at Kingsport has used the double shell semi-direct heat dryers with marked success and without operating difficulties have produced chips that are bone dry to the core.

Sulphur As a Material of Construction

Absorption in Wood or Concrete Produces New Construction Materials of Chemical Engineering Interest

INERT chemical properties of sulphur, especially its resistance to most acids, may be imparted to various structural materials used in the chemical industry under conditions of severe service. This is notably the case with both wood and concrete.

Wood is largely employed for the construction of storage tanks and other purposes, but one of its great defects is the breaking down through absorption allowing the acids or other corrosive substances to come in contact with the tie rods and metallic fastenings. Many species of wood are readily treated with sulphur by a simple open tank method, although vacuum and pressure inject a larger proportion of sulphur into resistant woods and greatly reduce the period of treatment. (See *Chem. & Met.*, vol. 33, No. 6, June, 1926.)

The treatment is particularly interesting in connection with tanks which may be knocked down, impregnated with sulphur and then assembled, and from experiments now being made, it appears that such tanks will swell to a sufficient degree ultimately to make tight joints. Such a treatment should be of interest in connection with the acid-proofing of large pickling tubs used in the steel and other metal industries, as well as wooden floor blocks oftentimes employed in the pickle rooms.

CONCRETE FOR SEVERE SERVICE

Concrete when injected with molten sulphur, becomes practically impervious and many times stronger as indicated by the curves. In the electrolytic field it has been very successfully used for treating large electrolytic cells now in operation for nearly two years at the plant of the Niagara Electrolytic Iron Co. in Niagara Falls. These cells, 130 in number, weighing 4,000 lb. each and about 14 feet long by 2½ feet in cross section, are under very severe service, the contained electrolyte consisting of a mixture of hot solution of ferrous and ferric chloride, and are performing very satisfactorily although not fully impregnated. The walls and bottoms of these cells are three inches thick and the sulphur penetrated uniformly for about one inch from all

sides, with only the center portions containing the reinforcement, untreated.

This was brought about in approximately eight hours by immersion in a bath of molten sulphur temporarily installed for this purpose. The metal reinforcement in concrete does not interfere with subsequent sulphur impregnation, but in many cases the very great strength imparted by the sulphur makes other reinforcement unnecessary, but un-

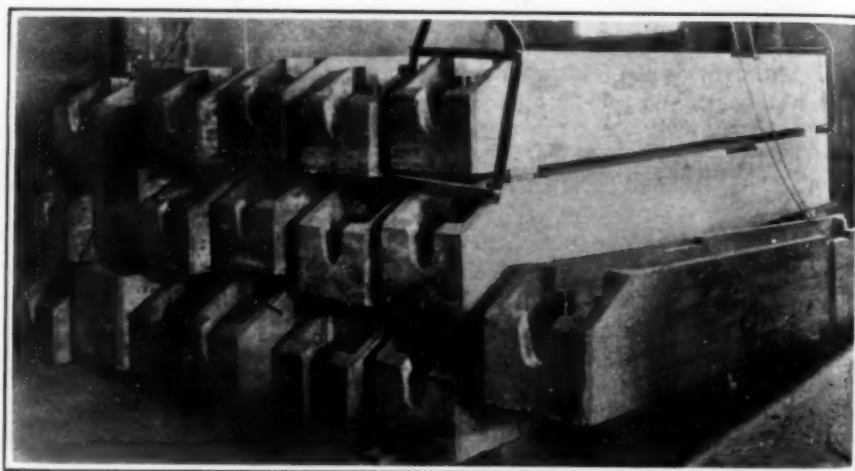


Fig. 1—Electrolytic Cells Made of Concrete Impregnated with Molten Sulphur

der severe conditions of stress it may be employed.

Sulphur is probably the only inexpensive elemental material which will withstand the action of a number of destructive chemicals, but the technique of its employment presents many problems, especially shrinkage upon solidification, lack of

physical strength and friability. By the use of materials or vehicles, however, which are in themselves resistant or partly resistant to corrosive action, the desirable qualities of sulphur may be imparted to them, greatly enhancing their value for containers or other uses in the chemical field.

In other cases, a high degree of porosity permits the use of vehicles for sulphur which may in themselves not be particularly resistant. For example, various fabrics absorb 80-90 per cent of sulphur and after treatment become, in effect, sulphur masses reinforced with cotton or other fibre. By so treating, certain

fabrics may be employed for exterior pipe line coverings or wrappings which resist destructive exterior conditions. Some of these sulphurized fabric coverings have been subjected to acid until the unprotected portions of the pipe were completely honeycombed, but with no action on the protected portion.

The work of finding practical applications for sulphur as a corrosion resisting material is being carried on in behalf of the Texas Gulf Sulphur Company by William H. Kobbé.

Rough Treatment for This Electric Motor

At the wet process cement plant of the Monolith Portland Cement Co. in California, a Westinghouse motor drives a 6-in. Wilfley centrifugal pump that handles the cement slurry before it enters the dry kiln. For apparently no reason at all an auto starter kicked out from overload. Upon investigation to discover the reason for this it was found that the pump had blown out a gasket,

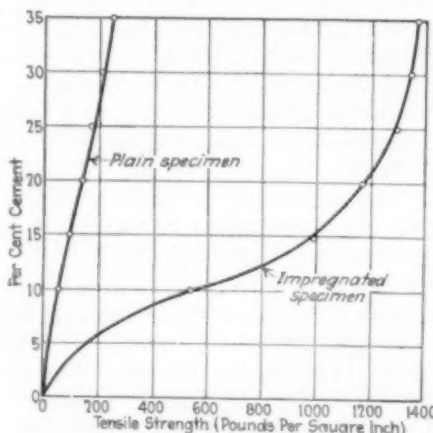
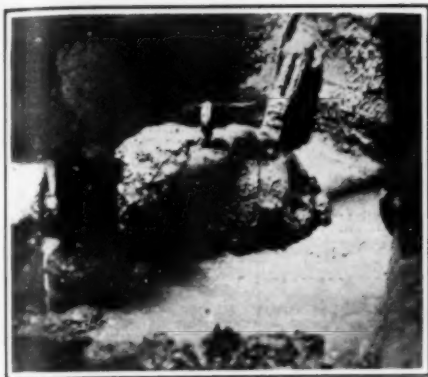


Fig. 2—Effect on Tensile Strength of Sulphur Impregnation of Concrete

These samples of concrete were impregnated after seven days aging. The tests were made by Division of Construction and Tests of the No. Carolina Highway Commission.



Electric Motor Buried Alive
in Cement Slurry

but the motor had continued to operate. The result was that the pit became filled with slurry and the motor completely buried, with only a portion of the eyebolt showing.

The pit was emptied immediately and the motor washed with a hose and water. Without changing the oil the motor was started up and found to be undamaged.

Grinding Phosphate Rock in Sulphuric Acid

Unusual Manufacturing Problem Solved by Design of New Acid-Proof Mill

IN THE CHEMICAL industry there are many manufacturing problems involving the treatment of materials with acid, the manufacture of phosphoric acid and superphosphates being a good example. In nearly all of the large plants, continuous processes have replaced intermittent, or batch, operation and with the development of continuous processes other equally attractive possibilities have presented themselves for solution. Among these is the method of grinding the raw material to the required fineness for further treatment.

Dry grinding predominates at the present time but it is costly and it is usually necessary to dry the crude material before it can be handled in dry grinding equipment. The second method is to grind in water by well-known methods which is usually less expensive than dry grinding, but where acid treatment is to follow, it is necessary to dewater the ground material before adding the acids and this step is objectionable, especially if a comparatively dry product is necessary. The ideal method is to grind in acid, thus eliminating both of the above objections, but the problem here is to find a grinding mill

that will stand against the severe conditions of combined abrasion and corrosion. In attempting to solve this problem, Ellery Wilson of the Rumford Chemical Co., Providence, R. I., is due much credit for having put into commercial use the first satisfactory continuous mill grinding in acid of which there is any record. The working out of a design of the mill was engineered by the Dorr Co. but it involved the very close co-operation of both the U. S. Rubber Co. and the Rumford Chemical Co., to make the machine a success.

The mill was made up as follows: An Abbé shell was lined by vulcanizing to the shell a $\frac{1}{4}$ -in. layer of acid resisting rubber. Next to this rubber lining were placed strips of hardwood laid in shiplap form parallel to the axis of the mill and then a silex block lining was placed on the inside. This gave a regular silex grinding surface with the shell protected from the action of the acid by the rubber and the hardwood strips protecting the rubber from being damaged by the silex blocks. This mill has been in satisfactory operation for about 18 months.

Unusual Applications for Phenol Resins

Unique Properties of These Synthetic Materials Make Possible Many Severe Service Uses

ELECTRICAL industries have found such extensive use for the phenol resin products that appear on the market under the trade marked names of Bakelite, Redmanol, Condensite, etc., that the extent to which the unique character of these products fits them for severe service in the mechanical and chemical industries is in danger of being overlooked.

As may be seen from the accompanying table (compiled from Bureau of Standards Technologic paper 216) the "laminated" and molded phenol resin products are infusible and withstand continuously temperatures up to about 300 deg. F., are insoluble in the ordinary solvents, are practically impervious to oils, absorb but little water, and are affected little or not at all by the organic and dilute mineral acids.

This unusual combination of properties becomes of industrial significance principally because the phenol resins have a unique molding property by which they may be cheaply and accurately fabricated. The raw resin in its primary state is quickly softened by moderate heat. Exposed to greater heat with pressure, however, it becomes permanently infusible; also it becomes hard, dense, strong and insoluble, and continued heating only accentuates these properties. These same basic properties are exhibited not only by the molded products, laminated products, and transparent resins but also by the enamels, lacquers and varnishes made from these resins.

Severe service applications of the phenol resins are to be found both in the mechanical and chemical

fields. In the mechanical field, gears made from the canvas laminated product, and grinding wheels in which the phenol resin serves as a binder for the abrasive materials, give remarkable performance under trying conditions. The gears show good wearing quality even when run in oil and when exposed to moisture. Bakelite bonding has greatly increased the rate of cutting as well as the life of grinding wheels. The infusibility of the binder makes possible operation at higher temperatures and its strength makes for longer life.

Among unusual chemical applications are the transparent Bakelite bottles and measuring cylinders for hydrofluoric acid. Also the resins may serve as protective coatings to be applied to less resistant materials. Bakelite enamel has been used to protect aluminum dryer plates from dilute hydrochloric and acetic acids; also for covering filter press plates handling oxalic acid. Varnish from the same material is used on wooden fume stacks exposed to the vapors of phosphoric acid. A steel centrifugal basket on which five separate coats of Bakelite varnish had been baked, was put in service in a New Jersey phosphoric acid plant in 1915. It has stood up under severe working conditions for eleven years.

A protective coating of phenol resin is said greatly to lessen the rate of attack by ultra violet light on hard rubber, which without such protection is discolored and disintegrated.

A new, flexible variety has been used with some success as a lining for kettles and other chemical equip-

Table I. Comparison of Properties of Hard Rubber, Vulcanized Fiber and Synthetic Phenol Resins

Properties	Hard Rubber	Vulcanized Fiber	Phenol Resins	
			Laminated	Molded
Dielectric strength (volts/mm.)	10,000 to 38,000	9,000 to 16,000	27,000 to 45,000	9,000 to 40,000
Tensile strength (lb. per sq. in.)	3,500 to 6,500	9,000 to 20,000	10,000 to 25,000	3,500 to 7,000
Water absorbed in 24 hours, percentage by weight.	0.02	26 to 45	0.2 to 1.0	0.05 to 0.2
Density (g./c.c.)	1.12 to 1.40	1.3 to 1.5	1.3 to 1.4	1.3 to 1.4
Thermal expansivity (at 20 deg. to 60 deg. C.)	60 to 80 $\times 10^{-6}$	27 $\times 10^{-6}$	20 to 30 $\times 10^{-6}$	25 to 45 $\times 10^{-6}$
Effect of age	Deteriorates slowly, but if properly vulcanized and protected from the light it is not affected.	Improves in quality by seasoning.	Improves	No depreciation in physical or chemical properties; slight increase in hardness.
Heat	At 65.5 deg. C. (150 deg. F.) pure hard rubber softens perceptibly; at 100 deg. C. (212 deg. F.) it is so soft it may be bent easily; at 115.5 deg. C. (240 deg. F.) it becomes leathery and may readily be cut with a knife; melts at 200 deg. C. (392 deg. F.).	Will not melt under any circumstances; not readily inflammable; at very high temperatures chars and becomes brittle; active combustion begins at about 343 deg. C. (650 deg. F.)	Not readily inflammable; will withstand continuously a temperature of 149 deg. C. (300 deg. F.); heat tends to complete the reaction and volatile substances are driven off; hence, when cooled it shrinks considerably and may split; shrinks and loses in weight above 60 deg. C.	See statement for laminated materials.
Sunlight	Discolors and disintegrates after a few months, the sulphur of the hard rubber is oxidized, forming the equivalent of sulphuric acid, this may take up ammonia from the air or may attack the filling materials forming the various sulphates upon the surface; the surface resistivity is greatly reduced.	No effect	No visible effect	After two and one-half years some materials show a slight change such as discoloration or very fine cracks; other materials show no such change.
Effect of ultra-violet light for 20 hours	Discolors and disintegrates; the action is as pronounced for a few hours' exposure to ultra-violet light as for many months exposure to sunlight; the surface resistivity is greatly reduced.	No data	Appreciable lowering of surface resistivity.	Appreciable lowering of surface resistivity.
Moist air	Hard-rubber compounds excepting those containing organic substances other than rubber are practically moisture-proof.	Absorbs water freely, but without permanent injury; while saturated it becomes soft and flexible and swells; warps and twists upon drying.	Absorbs slight amount of water, reducing dielectric properties.	Absorbs slight amount of water, reducing dielectric properties.
Steam	The only effect is that due to the high temperature.	Same as above, except absorption is more rapid.	Best grades not affected beyond slight absorption of moisture; after a few days in steam the cheaper grades will swell appreciably and split; superheated steam tends to warp and blister all grades of the material.	Absorbs a slight amount of moisture; if steam is superheated, the high temperature will cause decomposition.
Solvents:				
Acetone	Attacks, dissolving oils and free sulphur.	No permanent effect	No effect	No effect
Alcohol	Attacks to a slight degree	No permanent effect	No effect	No effect
Ammonia	No effect	No permanent effect	Strong solutions may cause material to swell.	No effect other than slight absorption of moisture
Aniline	Softens it at ordinary temperature.	Not known	Probably no effect	Probably no effect
Benzol	Softens it at ordinary temperature.	No permanent effect	Probably no effect	Probably no effect
Carbon bisulphide	Dissolves small amount of hard rubber and any free sulphur.	No permanent effect	Probably no effect	Probably no effect
Ether	Dissolves small amount of hard rubber and any free sulphur.	No permanent effect	No effect	Probably no effect
Naphtha	Softens and swells to slight extent.	No permanent effect	Probably no effect	Probably no effect
Oil of turpentine	Dissolves in boiling oil.	No permanent effect	Probably no effect	Probably no effect
Oil:				
Mineral	Slight softening	Slight absorption	Practically impervious	Practically impervious
Organic	Unaffected	Slight absorption	Practically impervious	Practically impervious
Effect of weak acids	Unaffected	Swells due to absorbed water; may be attacked after some time.	Practically unaffected except for absorption of water.	Practically unaffected
Weak caustic alkalis	Unaffected	Swells due to absorbed water; may be attacked after some time.	Does not successfully resist the action of alkali unless very dilute.	Does not successfully resist the action of alkali unless very dilute.
Stronger acids (HNO ₃ , HCl, H ₂ SO ₄)	Not attacked by concentrated hydrochloric, hydrofluoric, acetic acids; not attacked by sulphuric acid of less than 1.50 specific gravity or nitric acid of less than 1.12 specific gravity.	Cellulose fiber attacked; soon decomposes.	Decomposes; rapidly depends on specific gravity and temperature of acid.	Decomposes; rapidly depends on specific gravity and temperature of acid.
Stronger caustic alkalis	No effect	Cellulose fiber attacked; soon decomposes.	Binder and filler decompose	Completely destroys; speed of the reaction depends on the strength of the solution.
Ozone	Oxidizes and soon ruins it for electrical purposes.	No effect	Not known	Not known
Metallic inserts	Rapidly deteriorated by contact with iron or copper, the metals themselves being corroded; the inserts should be coated with tin, paper, unvulcanized rubber or other mutually protecting medium.	No effect	No effect	No effect
Machining qualities	Admits of a high polish; machines less accurately than would be supposed, due to great resiliency; the better the grade the more readily it is machined; quality may be judged roughly by color and texture, toughness, color and grain of a shaving; has tendency to warp; can be molded but not accurately to size.	Admits of a fine finish; may be sawed, punched, drilled, stamped, embossed, turned, planed, bent, tapped; tough, resists shock; cannot be molded.	Admits of a good polish; can be sawed, punched, drilled, stamped, turned, planed, knurled, embossed, milled, tapped either with or against the grain, though not as easily as hard rubber and vulcanized fiber; tough, resists shock; can not be molded.	Admits of a fine lasting polish; can be machined, cut, filed, sawed with difficulty; can be molded accurately to size; quite brittle.
Cost	About \$2 per pound in sheet form.	50 to 80 cents per pound up to 1 in. in thickness; about \$5 per pound for 2 in. in thickness.	About \$1 per pound	Cost varies with complexity of steel molds

ment which must resist abrasion as well as chemical action. Cloth laminated Bakelite vanes or buckets are used on a rotary pump handling corrosive mine water. The same material is formed into barrels used in electroplating operations. It is reported that molded Bakelite paddles used in copper and nickel plating baths were in excellent condition

after approximately a year of this type of service.

Few organic materials, natural or synthetic, exhibit stability under such trying conditions. It is not surprising, therefore, that the chemist and chemical engineer are continually finding the phenol resin products useful in new and unusual industrial applications.

Amorphous Silica for Severe Service

Fused Silica, Fused Quartz and a New Composition of Similar Properties Are Unusually Resistant to Extreme Chemical and Thermal Conditions

By William W. Winship

Manager, The Thermal Syndicate, Ltd., Brooklyn, New York

IN SELECTING materials for plant construction the chemical engineer must be guided in this choice by various considerations, such as (1) chemical inertness of the material in question (2) its resistance to high temperature exposure and to sudden temperature changes (3) physical properties and (4) economy. In investigating the qualifications of amorphous silica products under these various headings we shall also have occasion to define some of the terms used.

Chemical inertness must be considered from the standpoint of both manufacturing plant and product. If the apparatus will be acted upon chemically by the materials being processed, there is of necessity the introduction of impurities into the compound or substance under production and its contamination may be a far greater drawback than mere plant deterioration. No metal with the exception of platinum, and no ceramic product, can compare in chemical inactivity with silica. The silica minerals possess the same resistance to chemical action as manufactured amorphous silica products, but will not in general withstand severe temperature conditions and on this account and owing to their existence in finely divided or crystalline form they are not readily available for chemical plant use without undergoing the processes of fusion and shaping.

Comparing the chemical resistance of fused silica with that of other products commonly employed in chemical plant construction it is not only completely proof against the action of sulphuric acid of any strength at any temperature, but is also indifferent to the halogens with

the exception of fluorine, and will not impart the slightest color to nitric acid.

The ability of fused silica to withstand extreme temperature changes is in marked contrast to the susceptibility of most materials. This characteristic is of course based on the negligible expansion of fused silica with temperature rise and consequent small contraction when suddenly cooled. Strongly exothermic reactions can accordingly be carried out in fused silica apparatus with perfect safety, and if desired the heat of reaction may be dissipated by water cooling. In employing fused silica tubes or retorts for endothermic processes various portions of the same apparatus may be maintained at widely varying temperatures.

LIMITING TEMPERATURES

While the softening point of fused silica lies at about 1,450 deg. C., it is advisable in most cases to restrict its use to below 1,100 deg. C. on continuous operations, and if the surrounding atmosphere be strongly reducing it may be advisable to keep within 1,000 deg. C. as a maximum. These limiting temperatures correspond to the devitrification points of fused silica, at which critical temperatures the ware reverts from the amorphous to the crystalline state and gradually crumbles away with the consequent loss of mechanical strength. In cases where transparent fused quartz is employed the temperature limit may be extended upward perhaps as much as 200 deg. C.

It is sometimes erroneously assumed that the physical properties of fused silica apparatus are such

as to restrict its usefulness in chemical plant construction, but when these properties are examined carefully it will be found that the outstanding characteristics of fused silica recommend it for employment in practically all cases where unusual chemical, thermal and electrical conditions are to be encountered.

Desirable physical characteristics possessed by fused silica are high strength under compression, light weight, absence of latent strains of manufacture, unique electrical insulation value, and in the case of the clear fused quartz ware, transparency over practically the entire spectrum, affording visibility under high temperature operating conditions and allowing the free transmission of ultra-violet light.

Erection, operating and replacement costs necessarily loom large in chemical and metallurgical plants. In some cases, as in muriatic and nitric acid manufacturing equipment, the initial cost and erection expense of fused silica are so low as to present convincing arguments for its use, especially when negligible replacement costs are kept in mind. In other operations, initially higher cost will be more than offset by continuous successful operation under conditions where the replacement expense on other materials would be excessive. Properly installed with due regard to its inherent characteristics, fused silica apparatus is usually satisfactory and economical in service in direct proportion to the difficulty of the temperature, corrosion or electrical conditions encountered.

It has been found that by mixing finely divided fused silica with a solution of alkaline silicate, treating the resulting product with acid after drying, and removing the acid salt by washing, a composition is formed which possesses the same properties of chemical resistance and low expansion as characterize fused silica. In other words, we have a structure of amorphous silica consisting of fused silica bonded by gelatinous precipitated silica, the two materials being almost identical, from the practical standpoint, in their behavior under high temperature exposure or corrosion environment. This new product is not yet being marketed commercially but appears to be readily susceptible of molding at low temperatures and can probably be produced in varying degrees of porosity.

Industrial Uses for Pyroxylin Plastics

Many Unusual Applications as a Material of Construction
Were First Developed in the Chemical
Engineering Industries

PYROXYLIN plastics, under such trade names as Celluloid, Pyralin, Viscoloid, etc., are well known to the public through their many applications in toilet ware, automobile curtains, fountain pens and other articles of everyday life. It is not as well known, however, even to chemical engineers, that a number of important industrial uses have been developed for which these materials are uniquely suitable. The nitrating plants in which these products are made were the first to develop their use in pyroxylin storage tanks and circulating piping in conjunction with these tanks. It is of interest to note that a number of other industrial applications of this kind for plant and laboratory work can be made without the need of special tools or technique and using the material in its standard form of sheets, rods or tubes.

The useful characteristics of the pyroxylin plastics may first be summarized. Depending upon its composition the solid substance varies in specific gravity from 1.30 to 1.50 at 15 deg. C.; has a softening or melting point of 140 deg. F. (60 deg. C.) to 200 deg. F. (93.4 deg. C.); an ignition point of 320 deg. F. (160 deg. C.) to 374 deg. F. (190 deg. C.) as determined by the Bureau of Explosives standard test for pyroxylin materials; has a coefficient of expansion of .00010 to .00060 per inch per degree Centigrade at 37 deg. C.; a dielectric strength of 850 to 1,500 volts per mil; a refractive index of 1.450N_D to 1.500N_D (Abbé Refractometer); a thermal conductivity of .00030 to .00045; a spectral transmission of 80 to 85 per cent in the visible range and up to wave lengths of 0.2 micron which falls from 80 per cent to 0 in the wave length zone of from 0.2 to 0.3 micron, being practically opaque in a large portion of the infra red region. It has a tensile strength of 8 to 10 kg. per sq.mm. with a yield point of 6 to 8 kg. per sq.mm. and an elongation of 25 to 40 per cent, and is free from brittleness.

Pyroxylin plastic is practically unaffected by hydrocarbon and chlorinated hydrocarbon solvents, animal, vegetable and mineral oils, low concentrations of acids excepting acetic acid and formic acid at normal tem-

peratures, but is attacked by acids at elevated temperatures and by the action of alkalis in any appreciable concentration and organic solvents at practically all temperatures. It will absorb moisture, with a very slight change in volume up to 1.5 per cent to 3 per cent of its own weight, resulting in slight softening and increase in plasticity.

Its properties, both physical and chemical, can be made to meet almost every trade requirement for a thermoplastic composition excepting those which employ high temperatures and involve severe exposure to actinic light, as under these conditions it is prone to decompose and change color. It is relatively of quick flammability but not explosive, and under the influence of heat tends to lose its shape. Because of these facts, it should not be subjected to uses in which it is exposed for a long time to temperatures above 140 deg. F. (60 deg. C.).

APPLICATIONS IN INDUSTRY

Tank Lining. In the purification of nitrocellulose and other similar processes a pyroxylin lining in the beater and bleach tanks serves to avoid contamination with splinters from a wooden tank or with metallic impurities derived from a metal lining. It withstands the action of dilute acid or of bleach liquor. A nitrocellulose cement is used to anchor the sheets to the wood and to cover the joints between the sheets.

Perforated sheets are also used as a lining for electroplating barrels in which small metallic objects are plated.

Protective Coatings. Wooden paddles and metal forks used in nitrocellulose purification may advantageously be similarly covered. Charts and records subject to frequent handling are often protected by the use of two transparent sheets of pyroxylin held together by means of nitrocellulose cement, preferably with the aid of heat and pressure.

A holder with a transparent window, hung on or near a machine or piece of equipment serves to display production records, and the latter are kept clean and are not easily mislaid. On a desk the material constitutes an inexpensive substitute for the

plate glass tops frequently used. The surface is easily cleaned with soap and water.

Gage Glass and Windows. The transparent tubing or sheeting, not being brittle or subject to breakage, is in many cases to be preferred to glass for industrial uses. Sandwich, or safety glass (a composite of two sheets of glass with one of transparent pyroxylin) combines the advantages of both glass and pyroxylin, having the hard surface of the former and the non-shattering characteristics of the latter.

Face Masks. Masks are easily constructed from transparent pyroxylin plastic material to meet various conditions met in the industries and serve to protect the face and eyes against splashes of irritating or corrosive liquid or against the results of possible explosion of light laboratory apparatus. They should not be subjected to uses where high temperatures or actual flame are experienced.

Inspection Tables. For covering inspection and assembly tables and the like, choice may be made from a wide variety of colors, of one which contrasts with the color of the articles handled. The color is the same clear through the sheet, whereas that of a painted surface is lost with wear. The surface is not affected by oil and grease and is readily cleaned.

Burette Readers. A narrow strip bent around a laboratory burette, with ends cemented together to form a handle, may be moved up and down the tube as a marker or as an aid in reading.

Equipment Models. The material is easily machined or worked by hand and easily joined by cement, and is available in various colors which may be used for their own values or as symbols in the construction of small-scale models of new construction.

Other industrial uses of interest to the chemical engineer are as eye shades and glare shields, unbreakable containers for costly materials, funnels and piping for the same use, stencils, panels for electrical instruments, slide rules, drawing instruments, goggles, containers for acids and storage cells.

For this information regarding the industrial uses of pyroxylin plastics, we are indebted to James F. Walsh, manager of research and development for the Celluloid Company, and A. F. Randolph, of the Du Pont Viscoloid Company.

Patents Issued Sept. 7 to Oct. 12, 1926

Paper, Pulp and Sugar

Process of Producing Pulp High in Resistant Cellulose. George A. Richter, Berlin, N. H., assignor to Brown Company, Berlin, N. H.—1,602,553.

Process of Producing Chemical Wood Pulp. George A. Richter, Berlin, N. H., assignor to Brown Company, Berlin, N. H.—1,598,880.

Method of Making Sulphite-Cooking Liquors. George A. Richter, Berlin, N. H., assignor to Brown Company, Berlin, N. H.—1,599,488.

Process for the Manufacture of High Alpha-Cellulose Fiber. George A. Richter and Milton O. Schur, Berlin, N. H., assignors to Brown Company, Berlin, N. H.—1,599,489.

Process for the Recovery of Sulphur Dioxide from Blow-Pit Gases. George A. Richter and Wallace B. Van Arsdell, Berlin, N. H., assignors to Brown Company, Berlin, N. H.—1,599,490.

Method of and Means for Making Paper. James T. Murphy, Chicago, Ill., assignor of one-half to James L. Carey, Chicago, Ill.—1,602,545.

Process of Preparing Paper Half Stock. Alfred MacKay, Philadelphia, Pa.—1,599,831.

Method of and Means for Making Machine-Glazed Paper. Joseph M. Ward, Detroit, Mich., assignor to Detroit Sulphite Pulp & Paper Co., Detroit, Mich.—1,598,793.

Paper Drier. Arthur E. Broughton, Minneapolis, Minn.—1,602,644.

Process for the Manufacture of Crude Milk Sugar. Raymond W. Bell, Washington, D. C., assignor to the Government and the People of the United States of America.—1,600,573.

Evaporator for Ribbon Cane Sirup. Samuel W. Barnes, Barnum, Tex.—1,598,670.

Manufacture of Sugar. Eduard Fürber, Heidelberg, Germany, assignor to The International Sugar and Alcohol Company Limited.—1,599,462.

Rubber

Manufacture of Rubber Compounds. Robert Russell, Heaton Park, and Herbert Broomfield, Stockport, England, assignors to Latex Developments Limited, London, England.—1,601,772.

Process of Manufacturing Rubber Goods. Clayton Olin North, Tallmadge Township, Summit County, Ohio, assignor to The Rubber Service Laboratories Co., Akron, Ohio.—1,602,624.

Manufacture of Rubber. Chauncey C. Loomis, Yonkers, and Horace E. Stump, Brooklyn, N. Y., assignors, by mesne assignments, to The Hevea Corporation.—1,599,282.

Method of and Machine for Making a Rubberized Fibrous Material. William G. O'Brien, Akron, Ohio, assignor to The Goodyear Tire & Rubber Company, Akron, Ohio.—1,599,384.

Method of Making Rubberized Fibrous Compositions. William G. O'Brien and Paul Beebe, Akron, Ohio, assignors to The Goodyear Tire & Rubber Company, Akron, Ohio.—1,599,383.

Process for Devulcanizing Vulcanized Rubber and the Product Thereof. Cyrus Field Willard, San Diego, Calif.—1,602,062.

Petroleum Refining

Apparatus for Distilling Decomposable Materials. Warren K. Lewis, Newton, Mass., assignor to Humble Oil & Refining Company, Houston, Tex.—1,599,824.

Art of Distilling Easily-Decomposable Materials. Warren K. Lewis, Newton, Mass., assignor to Humble Oil & Refining Company, Houston, Tex.—1,599,825.

Apparatus for Cracking Oil. Carl M. Page, Geneva, Ill., assignor to George Fabian, Geneva, Ill.—1,598,618.

Improvement in Pyrogenetic Manufacture of Gasoline. Francis M. Rogers and Max O. Paulus, Whiting, Ind., assignors to Standard Oil Company, Chicago, Ill.—1,599,100.

Process and Apparatus for Cracking Hydrocarbon Oils. Warren F. Faragher, William Arthur Gruse, and Frederick Horace Garner, Pittsburgh, Pa., assignors to Gulf Refining Company, Pittsburgh, Pa.—1,601,727.

Process and Apparatus for Cracking Hydrocarbon Oils. Warren F. Faragher, William Arthur Gruse, and Frederick Horace Garner, Pittsburgh, Pa., assignors to Gulf Refining Company, Pittsburgh, Pa.—1,601,728.

Process and Apparatus for Cracking Hydrocarbon Oils. Warren F. Faragher,

Pittsburgh, and William A. Gruse, Wilkesburg, Pa., and Frederick R. Garner, Fawley, England, assignors to Gulf Refining Company, Pittsburgh, Pa.—1,601,730.

Apparatus for Cracking Oils. Loftus B. Cuddy, Bayhead, N. J.—1,598,805.

Process for Converting Hydrocarbons. Robert T. Pollock, Boston, Mass., assignor to Universal Oil Products Company, Chicago, Ill.—1,602,990.

Process of Decolorizing Petroleum Distillates. Ralph C. Pollock, Long Beach, Calif., assignor to Union Oil Company of California, Los Angeles, Calif.—1,602,703.

Production of Lower-Boiling Distillates from Higher-Boiling Petroleum Hydrocarbons. Almer McDuffie McAfee, Port Arthur, Tex., assignor to Gulf Refining Company, Pittsburgh, Pa.—1,601,636.

Method of Preparing an Emulsion for the Purification of Oils. Paul W. Prutzman and Paul D. Barton, Los Angeles, Calif., assignors to General Petroleum Corporation, Los Angeles, Calif.—1,599,715.

Process of Refining Mineral Lubricating Oils. James W. Weir, Fillmore, Calif.—1,603,174.

Process and Apparatus for Treating Bituminiferous Materials. Jay J. Jakowsky, Los Angeles, Calif.—1,602,819.

Process for Recovering Values from Oil Shales. Milton J. Trumble, Los Angeles, Calif.—1,598,831.

Retort for Treating Oil Shale. Edward B. Roth, St. Louis, Mo.—1,598,882.

Oil-Refining Still. Francis C. Moore and Perry Vandervort, Long Beach, Calif.—1,599,833.

Process of Distillation. Warren F. Faragher, William Arthur Gruse, and Frederick Horace Garner, Pittsburgh, Pa., assignors to Gulf Refining Company, Pittsburgh, Pa.—1,601,729.

Manufacture of Lubricants. Morris C. Van Gundy, Houston, and Joseph R. Scanlin, Port Arthur, Tex., assignors to The Texas Company, New York, N. Y.—1,599,854.

Process of Refining Mineral Oil. Theodore Helthaler, Granschutz, Germany, assignor to the Firm: Hugo Stinnes Riebeck Montan und Ölwerke Akt. Ges., Halle-on-the-Saale, Germany.—1,601,753.

Treating Hydrocarbon Oils. Edson R. Wolcott, Los Angeles, Calif., assignor to The Texas Company, New York, N. Y.—1,601,421.

Art of Treating Oils. George Kolsky, Jersey City, N. J.—1,598,973.

Process for Treating Hydrocarbon Oils. Joseph B. Weaver, Chicago, Ill., assignor to Oil Products Company, Toledo, Ohio.—1,601,786.

Oil-Treating Composition. Herman Reinhold, Omaha, Nebr.—1,600,845.

Process for Treating Hydrocarbons. Carben P. Dubbs, Wilmette, Ill., assignor to Universal Oil Products Company, Chicago, Ill.—1,600,721.

Method of Dehydrating Petroleum Emulsions. Harold C. Eddy, Los Angeles, Calif., and Gordon B. Hanson, Houston, Tex., assignors to Petroleum Rectifying Company of California, Los Angeles, Calif.—1,602,190.

Motor Fuel and Its Manufacture. Ernst Johansen, Fall River, Mass., assignor to New England Oil Refining Company, Fall River, Mass.—1,601,215.

Method of and Apparatus for Separating Petroleum Sludge. Ingenium Hechenbleikner and Thomas C. Oliver, Charlotte, N. C.—1,599,360.

Process of Revivifying Spent Filtering Materials. Stanley Hiller, San Francisco, Calif., assignor to Stanley Hiller, Inc., San Francisco, Calif.—1,598,967.

Process of Producing from Crude Petroleum Purified Asphaltic Residues. Sidney W. Moss, Morristown, N. J., assignor to The De Laval Separator Company, New York, N. Y.—1,599,369.

Fuels and Combustion

Fuel and Process for Producing Said Fuel. Edward Mallock, East Boston, Mass., assignor of one-half to William R. Green, Plainville, Mass.—1,601,501.

Peat-Fuel Production. Leonard Brown and Walter L. Brown, Proctor, Minn.—1,599,952.

Process of Producing Enriched Water Gas. Walter Edwin Trent, Washington, D. C., assignor to Trent Process Corporation, Washington, D. C.—1,600,375.

Gas Producer. Arthur Henry Lyman, Westminster, London, and Niels Edward Rambush, Stockton-on-Tees, England.—1,599,022.

Sludge Tank and Gas Producer. Henry L. Thackwell, Dallas, Tex., assignor of one-half to Fred A. Jones, Dallas, Tex.—1,599,731.

Coke Oven and the Like. Arthur Roberts, Evanston, Ill., assignor, by mesne assignments, to Chicago Trust Company, trustee, Chicago.—1,601,741.

Process of Recovering Light Oils from Residual Products. Alfred Oberle, Oak Park, Ill., assignor of one-half to Thomas E. Scofield, Kansas City, Mo.—1,599,429.

Process of Making Fuel Briquettes. Georg Plochmann, Teplitz-Schonau, Czechoslovakia.—1,600,065.

Waste-Heat Boiler. Franz Fr. Bürger, Mannheim, Germany, assignor, by mesne assignments, to Heinrich Lanz, Aktiengesellschaft, Mannheim, Baden, Germany.—1,599,406.

Recuperative Apparatus. Frank A. Fahrenwald, Cleveland Heights, Ohio.—1,599,613.

Method and Apparatus for Burning Clayware. Willard D. Richardson, Columbus, Ohio.—1,599,589.

Sectional Retort for Retort Kilns. Robert Sayre Kent, Brooklyn, N. Y.—1,602,678.

Tunnel Kiln. Laurence Arthur Vincent, Pleasantville, Pa., assignor to American Dressler Tunnel Kilns, Inc., Cleveland, Ohio.—1,601,748.

Cellulose and Plastics

Manufacture of Viscose Films, Etc. Jacques Edwin Brandenberger, Neuilly-sur-Seine, France.—1,601,289.

Method of Impregnating Cellulose Fibers. William W. Carter, Needham, Mass.—1,598,640.

The Process for Reducing the Viscosity Characteristics of Nitrocellulose. William R. Webb, Rochester, N. Y., assignor to Eastman Kodak Company, Rochester, N. Y.—1,598,949.

Process for Reducing the Viscosity characteristics of Nitrocellulosic Materials. Victor E. Kimmel, Rochester, N. Y., assignor to Eastman Kodak Company, Rochester, N. Y.—1,598,972.

Manufacture and Production of Threads, Filaments, Strips, or Films from Cellulose Compounds. Horace James Heggan, Coventry, England, assignor to Courtaulds Limited, London, England.—1,599,233.

Dyeing of Cellulose Acetate. George Holland Ellis, Francis Malcolm Stevenson, and Cyril Mansley Croft, Spondon, near Derby, England, assignors to American Cellulose and Chemical Manufacturing Company, Limited.—1,600,277.

Manufacture and Production of Threads, Filaments, Strips, or Films from Cellulose Ethers. Walter Hamis Glover, Bedford, England, assignor to Courtaulds Limited, London, England.—1,599,230.

Making Cellulose Acetate Directly Spinable from Reaction Mixtures in Commercial Form. Joe Olgierd Zdanowich, London, England.—1,600,159.

Cellulose-Ester Plastic and Solution. Otto Schmidt, Theodor Eichler, and Karl Seydel, Ludwigshafen-on-the-Rhine, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfurt-on-the-Main, Germany.—1,600,700.

Process of Dyeing Cellulose Ethers. Heinz Eichwede and Elch Fischer, Höchst-on-the-Main, Germany, assignors to Grasselli Dyestuffs Corporation, New York, N. Y.—1,599,748.

Purification of Cellulose Ethers. Jean Altwegg and Charles Antoine Madlhard, Lyon, France, assignors to Societe Chimique des Usines du Rhone, Paris, France.—1,599,508.

Fermentation of Cellulosic Materials. Herbert Langwell, Epsom, England.—1,602,306.

Cellulose-Ether Solvent and Composition. Leon Lillienfeld, Vienna, Austria.—1,599,569.

Process for Manufacturing Artificial Silk. Masaru Hirsawa, Tokyo-Fu, Japan, assignor to Shozaburo Hoshino, Yokohama, Japan.—1,603,080.

Dyes and Organic Compounds

Process for the Preparation of New Derivatives of Naphthoquinone. André Wahl, Enghien, and Robert Lantz, Paris, France, assignors to Societe Anonyme des Matieres Colorantes et Produits Chimiques de Saint-Denis, Paris, France.—1,599,444.

N - Acidoaminoalkyl - Amino-naphthalene Azo Dyestuffs. Walter Luisberg, Leverkusen, near Cologne, and Winifrid Hentrich, Johann Huismann, and Ludwig Zeh, Wiesdorf, near Cologne, Germany, assignors to Grasselli Dyestuff Corporation, New York, N. Y.—1,603,002.

Trisazo Dyestuff. Hugo Schwietzer, Weisdorf, near Cologne, assignor to Grasselli Dyestuff Corporation, New York, N. Y.—1,602,991.

Azo Dyestuffs and Process of Making Same. Max Isler and Lukas von Mehel, Basel, Switzerland, assignors to Society of Chemical Industry in Basle, Basel, Switzerland.—1,600,763.

Process of Making Benzantrone and Its Derivatives. Ferdinand W. Peck, Penns Grove, N. J., and John H. Sachs, Wilmington, Del., assignors to E. I. du Pont de Nemours & Company, Wilmington, Del.—1,601,319.

Alkyl-Arylsuphaminonaphthol Sulphonic Acid Azo Dyes. Wilhelm Neelmeier, Leverkusen, near Cologne, and Theodore Nocken, Weisdorf, near Cologne, Germany, assignors to Grasselli Dyestuff Corporation, New York, N. Y.—1,602,776.

Method of Manufacturing Benzol. Ira W. Henry, Greenwich, Conn., assignor of three-twentieths to Joseph E. Stevens, New York, N. Y.; one-twentieth to Edward S. Beach, Ridgefield, Conn.; one-tenth to Courtland Linkroom, Hackensack, N. J.; and one-tenth to Arthur Woods, New York, N. Y.—1,601,213.

Process of Obtaining Pure Anthracene and Carbazol from Crude Anthracene. Leopold Well, Hamburg, Germany.—1,601,749.

Halogenated Indigoid Dyestuffs. Hermann Staulinger, Zurich, Richard Tobler and Robert Stocker, Basel; Jakob Müller, Munchenstein, near Basel, and Armin Bucher, Basel, Switzerland, assignors to the Firm Society of Chemical Industry in Basle, Basel, Switzerland.—1,600,743.

Thiophenol-Sulphonic Acid Tanning and Mordanting Agents. Alfred Thausen, Deutz, near Cologne, Germany, assignor, by mesne assignments, to Grasselli Dyestuff Corporation.—1,600,525.

Production of Tetrazoles. Karl Friedrich Schmidt, Heidelberg, Germany, assignor to Knoll & Co., Ludwigshafen-on-the-Rhine, Germany, a firm composed of Albert Knoll, Hans Knoll, and Max Daegle.—1,599,493.

Process for the Production of Solid Alcohol Structure Soaps. Richard Falck, Munden-in-Hanover, Germany.—1,601,244.

Method of Purifying Aromatic Alcohols and Derivatives. Mark E. Putnam and Joseph W. Bitton, Midland, Mich., assignors to The Dow Chemical Company.—1,601,509.

Purifying Alcohols. Matthew D. Mann, Jr., Roselle, and Robert B. Lebo, Elizabeth, N. J., assignors to Standard Development Company.—1,601,404.

Process of Resinifying Aliphatic Aldehydes. Willy O. Herrmann and Hans Deutsch, Munich, Germany, assignors to Consortium für Elektrochemische Industrie G. m. b. H., Munich, Germany.—1,600,113.

Process of Making Methyl Alcohol. Stephen P. Burke, New York, N. Y., assignor to Ralph H. McKee, New York, N. Y.—1,602,846.

Process for the Recovery of Alcohol, Organic Acids, and Fertilizer from Fermented Saccharine Materials. Gustave T. Reich, Anaheim, Calif.—1,599,185.

Purification of Crude Alcohols. René de M. Taveau, Elizabeth, N. J., assignor to The Texas Company, New York, N. Y.—1,600,437.

Process of Dealkoholization of Beverages and the Like. Charles H. Caspar, Philadelphia, Pa.—1,598,601.

Process for the Rapid Fixing of Ethylene by Means of Sulphuric Acid for the Purpose of Obtaining Neutral Ethyl Sulphate. Augustin Amédée Louis Joseph Damiens, Sevreux, Marie Charles Joseph Elysee de Loisy, Paris, France, and Olivier Joseph Gislain Piette, Brussels, Belgium.—1,599,119.

Purification of Alkali-Metal Xanthate Solutions. Wilhelm Hirschkind, Pittsburg, Calif.—1,601,068.

Plastic and Process of Making the Same. William Arthur Collings, Santa Monica, Calif.—1,601,295.

Apparatus for Hydrogenating Oils. Edward L. Anderson, Long Beach, Calif., assignor of one-fourth to Edward F. Therleau, Long Beach, Calif.—1,599,629.

Preparation of Butyric Acid. Charles O. Young, Elmhurst, N. Y., assignor to Carbide and Carbon Chemicals Corporation.—1,599,737.

Processes and Apparatus for Producing Acetic Acid from Acetaldehyde. Erik Gustaf Thorin, Mansbo, Avesta, Sweden, assignor to Stockholms Superfosfat Fabriks Aktiebolag, Stockholm, Sweden.—1,601,891.

Process for Removing the Hair from Green Hides. Max Bergmann, Eugen Immenhöfer, and Alice Immenhöfer, née Goodson, Dresden, Germany.—1,599,358.

Tanning Material and Process of Producing Same. John K. Tullis, New York, N. Y.—1,603,169.

Process of Securing Uniform Revivification of Activated Carbon. Victor S. Allien, New York, N. Y., assignor to Darco Sales Corporation, New York, N. Y.—1,599,072.

Disaccharide Anhydrides and Polymerization Products Thereof and Process of Making Same. Amé Pictet, Geneva, Switzerland, assignor to The Society of Chemical Industrial in Basle, Basel, Switzerland.—1,602,549.

Process for Producing Saccharine. John Wesley Orelup, Springfield, N. J.—1,601,505.

Process of Separating Proteins and Other Matter from Whey in Soluble Form. Raymond W. Bell, Washington, D. C., dedicated to the Government and the People of the United States.—1,600,161.

Process of Improving Steam-Distilled Wood Turpentine. Daniel L. Sherck, De Quincy, La.—1,600,143.

Hydrogenation and Production of Non-sludging Oils. Herbert Raymond Moody, New York, N. Y.—1,601,406.

Yeast Assistant. Augustus H. Fliske, Warren, R. I., assignor to Rumford Chemical Works, Providence, R. I.—1,599,563.

Mercury Compound. Oskar Neubert, Karl Schranz, and Georg Wessenberg, Elberfeld, near Cologne-on-the-Rhine, Germany, assignors to Winthrop Chemical Company, Inc., New York, N. Y.—1,602,777.

Inorganic Compounds

Process of Making Diammonium Phosphate. Henry Blumenberg, Jr., Los Angeles, Calif., assignor to Stockholders Syndicate, Los Angeles, Calif.—1,601,233.

Process of Purifying Phosphoric Acid. Arthur B. Gerber, Anniston, Ala., assignor to Federal Phosphorus Company, Birmingham, Ala.—1,601,208.

Fertilizer. Joseph M. Braham and Franklin E. Allison, Washington, D. C.—1,598,638.

Fertilizer. George Barsky, New York, N. Y., assignor to American Cyanamid Company, New York, N. Y.—1,599,198.

Fertilizer Corrective. Frederick W. Freise, Palmyra, N. J., assignor to American Cyanamid Company, New York, N. Y.—1,599,226.

Insecticide. Julian S. Cohen and Allan B. Leeburger, New York, N. Y., assignors to Interstate Chemical Company, Jersey City, N. J.—1,599,809.

Process for Forming Metal Compounds and Mixtures Involving Phosphorus. William Koehler, Cleveland, Ohio.—1,599,618.

Method and Apparatus for Making Glass. Elihu Thomson, Swampscott, Mass., assignor to General Electric Company.—1,603,221.

Apparatus for Making Sheet Glass. Frederick Gelstharf, Tarentum, Pa., assignor to Pittsburgh Plate Glass Company.—1,598,770.

Apparatus for Making Sheet Glass. Walter G. Koupal and Joseph S. Gregorius, Mount Vernon, Ohio, assignors to Pittsburgh Plate Glass Company.—1,598,729.

Process and Apparatus for Making Sheet Glass. Walter G. Koupal, Mount Vernon, Ohio, assignor to Pittsburgh Plate Glass Company.—1,598,730.

Process of Making Cement by the Wet Method. Thomas Rigby, Westminster, London, England.—1,600,846.

Method of Manufacturing Pottery Ware. Edward S. Lea, Morrisville, Pa., assignor to Carrier Engineering Corporation, Newark, N. J.—1,600,286.

Refractory Products and Their Manufacture. Frederic Charles Fridtjof le Coultre, Marseille, France, assignor to Societe d'Etude des Agglomerés, Paris, France.—1,602,273.

Photographic Emulsion with Mercury Compound and Process of Making the Same. Samuel E. Sheppard and James H. Hudson, Rochester, N. Y., assignors to Eastman Kodak Company, Rochester, N. Y.—1,602,589.

Photographic Light-Sensitive Material containing Tellurium and Process of Making the Same. Samuel E. Sheppard, Rochester, N. Y., assignor to Eastman Kodak Company, Rochester, N. Y.—1,602,591.

Photographic Light-Sensitive Material Containing Selenium and Process of Making the Same. Samuel E. Sheppard, Rochester, N. Y., assignor to Eastman Kodak Company, Rochester, N. Y.—1,602,592.

Fluorescent Material and Method of Preparing Same. Samuel E. Sheppard, Rochester, N. Y., assignor to Eastman Kodak Company, Rochester, N. Y.—1,602,593.

Fluorescent Material and Method of Preparing Same. Samuel E. Sheppard, Rochester, N. Y., assignor to Eastman Kodak Company, Rochester, N. Y.—1,602,594.

Recovery of Cyanide. Le Roy Wilbur Heffner, East Norritown Township, Montgomery County, and William Tiddy, Jeffersonville, Pa., assignors to Rainey-Wood Process Corporation, New York, N. Y.—1,600,228.

Process for the Production of Hydrocyanic Acid. Georg Bredig and Egon Elßd, Karlsruhe, Germany, assignors to the Firm of Rudolph Koepf & Co., Oestrich-on-the-Rhine, Germany, a Society organized under the laws of Germany.—1,598,707.

Manufacture of Aluminum Chloride. Richard J. Dearborn, Summit, N. J., assignor to The Texas Company, New York, N. Y.—1,600,216.

Process of Making Aluminum Halides and Alkaline-Earth-Metal Carbides. John R. Mardick, New York, N. Y., assignor to

Union & Carbon Research Laboratories, Inc.—1,600,899.

Process for Producing Chemically Pure Sodium Chloride from Natural Brine. Clinton S. Robison, Chicago, Ill., assignor to Mulkey Salt Co., Detroit, Mich.—1,598,935.

Production of Bromine. Robert E. Wilson, Chicago, Ill., assignor to Standard Oil Company, Whiting, Ind.—1,599,108.

Lithopone and Process for Producing the Same. William J. O'Brien, Baltimore, Md., assignor to The Glidden Company, Baltimore, Md.—1,600,772.

Lithopone and Process for Producing the Same. William J. O'Brien, Baltimore, Md., assignor to The Glidden Company, St. Helena, Baltimore, Md.—1,600,773.

Recovering Sulphur. Josef Jannek, Ludwigshafen-on-the-Rhine, Germany, assignor to I. G. Farbenindustrie Aktiengesellschaft, Frankfurt-on-the-Main, Germany.—1,599,363.

Process and Apparatus for Exothermic Catalytic Reactions. Harry D. Gibbs, Penns Grove, N. J., assignor to E. I. du Pont de Nemours & Company, Wilmington, Del.—1,599,228.

Oxidizing Catalyst. Joseph C. W. Frazer, Baltimore, Md.—1,602,404.

Cyanide Product and Process of Producing the Same. Kenneth F. Cooper, Great Neck, N. Y., assignor to American Cyanamid Company, New York, N. Y.—1,599,212.

Method of Electric Formation of Oxides of Nitrogen. James S. Island, Merriton, Ontario, Canada.—1,601,500.

Process for Removing Hydrogen Sulphide from Gases. Theodor Petrus Ludovicus Petit, Velsen, Netherlands.—1,598,985.

Process for the Concentration of Diluted Nitrous Gases. Henry Johnsen, Notodden, Norway, assignor to Norsk Hydro Elektrisk Kvaestofaktieselskab, Oslo, Norway.—1,600,547.

Cleaning Compound and Process of Preventing the Deliquescence of a Salt. Howard E. Fritz, Columbus, Ohio, assignor to The Smith Agricultural Chemical Company, Columbus, Ohio.—1,599,996.

Reduction of Rare-metal Oxides. John W. Marden, Swissvale, Pa., assignor to Westinghouse Lamp Company.—1,602,542.

Electrochemistry

Production of Depolarizing Agent for Voltaic Battery. Thomas A. Edison, West Orange, N. J., assignor to Thomas A. Edison, Incorporated, West Orange, N. J.—1,599,121.

Carbon for Depolarizing Compositions and Process of Conditioning the Same. George W. Helse, Bayside, N. Y., assignor to National Carbon Company, Inc.—1,602,850.

Dry Battery or Battery with a Solidified Electrolyte. René Oppenheim, Levallois-Perret, France, assignor to Societe Anonyme Le Carbone, Levallois-Perret, France.—1,599,061.

Electrolyte for Electrolytic Cells. Campbell C. Carpenter, East Cleveland, Ohio, assignor to Willard Storage Battery Company, Cleveland, Ohio.—1,600,397.

Process of and Apparatus for Use in Electrolytic Purification of Graphite. Leonidas C. Haffner, Chicago, Ill.—1,600,730.

Electrolytic Process of Preparing Silver Halides from Metallic Silver. Samuel E. Sheppard and Raymond H. Lambert, Rochester, N. Y., assignors to Eastman Kodak Company, Rochester, N. Y.—1,602,595.

Electrodeposition of Metallic Chromium. Elji Suzuki, Tokyo, Japan, assignor to General Electric Company.—1,600,076.

Chemical Engineering Equipment

Gyratory Crusher. Edgar B. Symons, Hollywood, Calif., assignor to Symons Brothers Company, Bakersfield, Calif.—1,600,780.

Mill. Oscar H. Johnson, Denver, Colo., assignor to The Mine and Smelter Supply Company, Denver, Colo.—1,602,434.

Mill. Oscar H. Johnson, Denver, Colo., assignor to The Mine and Smelter Supply Company, Denver, Colo.—1,602,435.

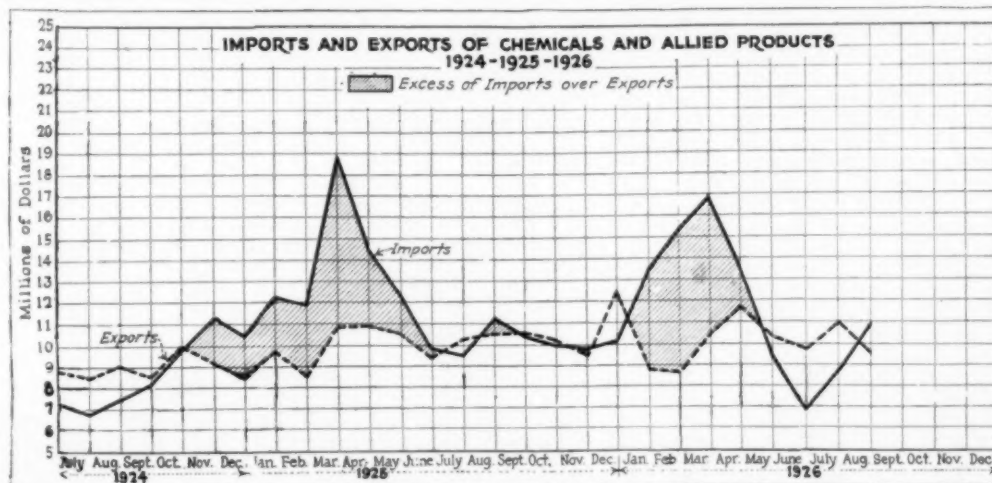
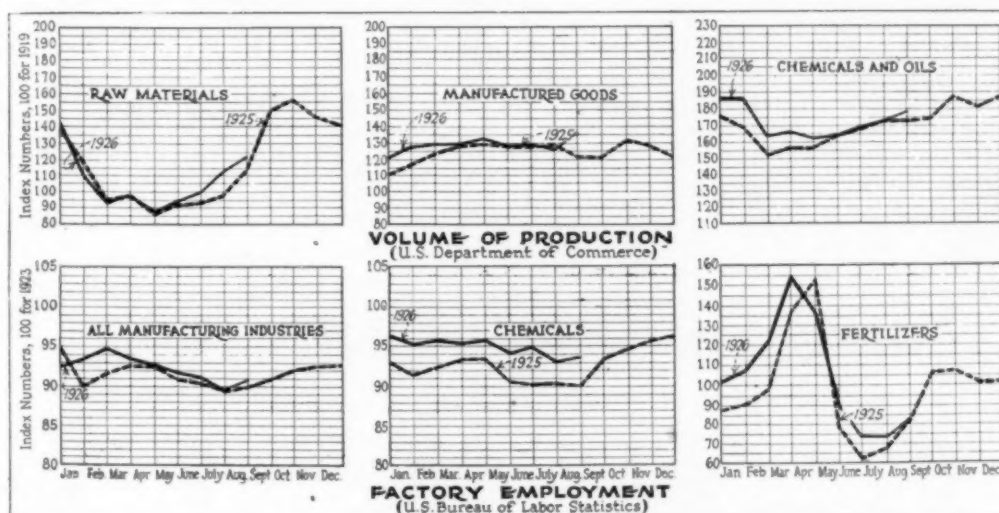
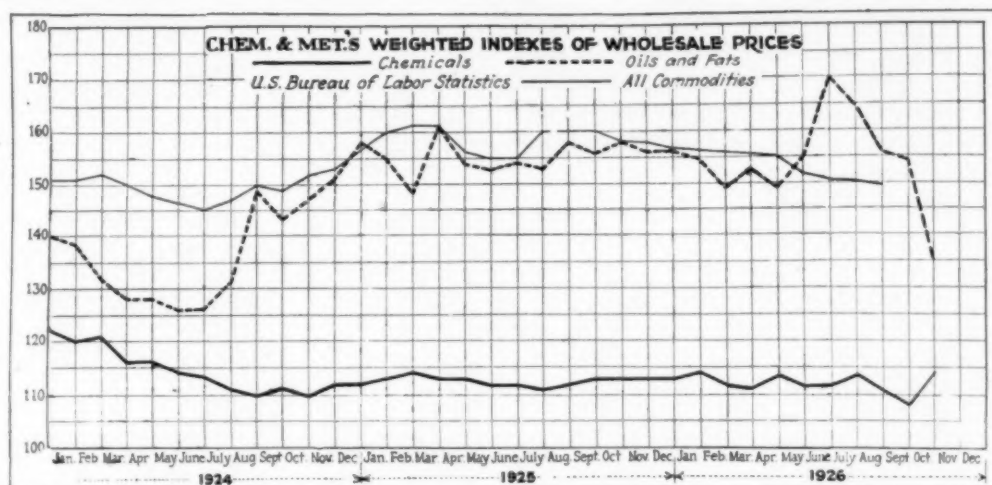
Pulverizing Mill. Alexander Mahaffey Read, Columbus, Ohio.—1,598,933.

Pulverizing Apparatus. John E. Bell, Brooklyn, N. Y., and William J. A. London, Hartford, Conn., assignors to International Combustion Engineering Corporation.—1,598,702.

Heat-Exchange Apparatus. Karl Muhleisen, Philadelphia, Pa., assignor to Schutte and Koerting Company, Philadelphia, Pa.—1,599,370.

High-Pressure Heat Exchanger. Charles F. Richey and Paul Y. Duffee, Franklin, Pa., assignors, by mesne assignments, to The Motor Fuel Corporation, Franklin, Pa.—1,602,552.

Heat Exchanger. Joseph Price, New York, N. Y., assignor to The Griscom-Russell Company, New York, N. Y.—1,600,013.

CHEM. & MET. Statistics of Business*In the Chemical Engineering Industries*

Current Prices in the New York Market

For Chemicals, Oils and Allied Products

The following prices refer to round lots in the New York Market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to October 18.

Industrial Chemicals

	Current Price	Last Month	Last Year
Acetone, drums.....lb.	\$0.12-\$0.13	\$0.12-\$0.13	\$0.12-\$0.13
Acid, acetic, 28%, bbl.....cwt.	3.25-3.50	3.25-3.50	3.00-3.25
Boric, bbl.....lb.	.09-.10	.09-.10	.08-.10
Citric, kegs.....lb.	.44-.45	.44-.47	.45-.47
Formic, bbl.....lb.	.10-.11	.10-.11	.10-.10
Gallie, tech., bbl.....lb.	.50-.55	.50-.55	.45-.47
Hydrofluoric 30% carb. lb.	.06-.07	.06-.07	.06-.07
Lactic, 44%, tech., light, bbl. lb.	.13-.14	.13-.14	.13-.14
22%, tech., light, bbl. lb.	.06-.07	.06-.07	.06-.07
Muriatic, 18%, tanks.....cwt.	.80-.85	.80-.85	.80-.85
Nitric, 36%, carboys.....cwt.	.05-.05	.05-.05	.04-.04
Oleum, tanks, wks.....ton	18.00-20.00	18.00-20.00	16.00-17.00
Oxalic, crystals, bbl.....lb.	.10-.11	.10-.11	.10-.11
Phosphoric, tech., 85%, lb.	.07-.07	.07-.07	.07-.08
Sulphuric, 60%, tanks.....ton	10.50-11.00	10.50-11.00	8.50-9.50
Tannic, tech., bbl.....lb.	.35-.40	.35-.40	.45-.50
Tartaric, powd., bbl.....lb.	.29-.30	.29-.30	.27-.30
Tungstic, bbl.....lb.	1.00-1.20	1.00-1.20	1.20-1.25
Alcohol, ethyl, 190 p.f. U.S.P. bbl.	4.75-4.80	4.75-4.80	4.90-.....
Alcohol, Butyl, dr.....lb.	.19-.20	.19-.20	.27-.30
Denatured, 190 proof			
No. 1 special dr.....gal.	.31-.36	.31-.36	.54-.....
No. 5, 188 proof, dr.....gal.	.31-.33	.31-.33	.53-.....
Alum, ammonia, lump, bbl. lb.	.03-.04	.03-.04	.03-.04
Chrome, bbl.....lb.	.05-.05	.05-.05	.05-.06
Potash, lump, bbl.....lb.	.02-.03	.02-.03	.02-.03
Aluminum sulphate, com., bags.....cwt.	1.40-1.45	1.40-1.45	1.40-1.45
Iron free, lb.....cwt.	2.00-2.10	2.00-2.10	2.40-2.45
Aqua ammonia, 26%, drums. lb.	.03-.04	.03-.04	.06-.06
Ammonia, anhydrous, cyl. lb.	.13-.15	.13-.15	.28-.30
Ammonium carbonate, powd. tech., casks.....lb.	.08-.09	.08-.09	.11-.11
Sulphate, wks.....cwt.	2.40-.....	2.40-.....	2.80-.....
Amylacetate tech., drums. gal.	1.60-1.75	1.75-1.85	2.75-3.00
Antimony Oxide, bbl.....lb.	.16-.16	.16-.16	.16-.16
Arsenic, white, powd., bbl. lb.	.03-.04	.03-.04	.03-.04
Red, powd., kegs.....lb.	.10-.11	.10-.11	.12-.12
Barium carbonate, bbl.....ton	50.00-52.00	52.00-52.00	48.00-50.00
Chloride, bbl.....ton	63.00-65.00	63.00-65.00	58.00-60.00
Nitrate, cask.....lb.	.07-.08	.07-.08	.07-.08
Blanc fixe, dry, bbl.....lb.	.03-.04	.03-.04	.03-.04
Bleaching powder, f.o.b., wks. drums.....cwt.	2.00-2.10	2.00-2.10	1.90-.....
Borax, bbl.....lb.	.05-.05	.05-.05	.05-.05
Iodine, ca.....lb.	.45-.47	.45-.47	.47-.48
Calcium acetate, bags.....cwt.	3.25-3.50	3.25-3.50	2.75-2.80
Arsenate, dr.....lb.	.08-.11	.08-.10	.07-.08
Carbide drums.....lb.	.05-.06	.05-.06	.05-.05
Chloride, fused, dr., wks. ton	21.00-.....	21.00-.....	21.00-.....
Phosphate, bbl.....lb.	.07-.07	.07-.07	.06-.07
Carbon bisulphide, drums. lb.	.05-.06	.05-.06	.05-.06
Tetrachloride drums.....lb.	.06-.07	.06-.06	.07-.07
Chlorine, liquid, tanks, wks. lb.	.04-.04	.04-.04	.04-.04
Cylinders.....lb.	.05-.08	.05-.08	.05-.08
Cobalt oxide, cans.....lb.	2.10-2.20	2.10-2.20	2.10-2.25
Copperas, bags, f.o.b. wks. ton	16.00-20.00	16.00-18.00	13.00-14.00
Copper carbonate, bbl.....lb.	.17-.17	.17-.18	.16-.17
Cyanide, tech., bbl.....lb.	.49-.50	.49-.50	.49-.50
Sulphate, bbl.....cwt.	4.80-4.90	4.75-5.00	4.90-4.60
Cream of tartar, bbl.....lb.	.21-.22	.21-.22	.21-.22
Epsom salt, dom., tech., bbl. cwt.	1.75-2.15	1.75-2.00	1.75-2.00
Imp., tech., bags.....cwt.	1.15-1.25	1.15-1.25	1.35-1.40
Ethyl acetate, 85% drums. gal.	.74-.76	.74-.76	.87-.90
99%, dr.....gal.	.95-.96	.95-.96	1.03-1.06
Formaldehyde, 40%, bbl. lb.	.10-.11	.10-.10	.08-.09
Furfural, dr.....lb.	.15-.17	.15-.17	.23-.....
Fusel oil, crude, drums.....gal.	1.35-1.40	1.40-1.50	2.40-2.50
Refined, dr.....gal.	2.50-3.00	2.50-3.00	3.25-3.50
Glauber salt, bags.....cwt.	1.00-1.15	1.00-1.10	1.20-1.40
Glycerine, c.p., drums, extra. lb.	.29-.30	.29-.30	.19-.19
Lead:			
White, basic carbonate, dry, casks.....lb.	.10-.10	.10-.10	.10-.10
White, basic sulphate, ask. lb.	.12-.12	.12-.12	.12-.12
Red, dry, ask.....lb.	.14-.15	.14-.15	.14-.14
Lead acetate, white crys., bbl. lb.	.14-.15	.14-.15	.13-.14
Lead arsenate, powd., bbl. ton	8.50-.....	8.50-.....	8.50-.....
Lime, chem., bulk.....lb.	.11-.11	.11-.11	.12-.12
Litharge, powd., ask.....lb.	.05-.06	.05-.06	.06-.06
Lithopone, bags.....lb.	.06-.06	.06-.06	.06-.07
Magnesium carb., tech., bags. lb.	.75-.77	.70-.72	.58-.62
Methanol, 95%, dr.....gal.	.77-.78	.72-.73	.60-.64
97%, dr.....gal.	.10-.10	.10-.10	.09-.10
Nickel salt, double, bbl. lb.	.10-.11	.10-.11	.10-.11
Single, bbl.....lb.	.14-.14	.14-.14	.16-.16
Orange mineral, ask.....lb.	.62-.65	.62-.65	.70-.75
Phosphorus, red, casks.....lb.	.32-.33	.32-.34	.34-.36
Yellow, casks.....lb.	.08-.08	.08-.08	.08-.08
Potassium bichromate, casks. lb.	.05-.06	.06-.06	.06-.06
Carbonate, 80-85%, cask. lb.	.08-.09	.08-.09	.08-.09
Chlorate, powd.....lb.	.55-.57	.55-.58	.47-.62
Cyanide, cs.....lb.			

	Current Price	Last Month	Last Year
First sort, cask.....lb.	\$0.09-\$0.09	\$0.08-\$0.09	\$0.08-\$0.08
Hydroxide (caustic potash) dr. lb.	.07-.07	.07-.07	.07-.07
Muriate, 80% bgs.....ton	34.90-.....	34.90-.....	34.55-.....
Nitrate, bbl.....lb.	.06-.06	.06-.06	.06-.07
Permanganate, drums.....lb.	.14-.15	.14-.15	.14-.15
Prussiate, yellow, casks.....lb.	.18-.18	.18-.18	.18-.18
Sal ammoniac, white, casks. lb.	.05-.06	.05-.06	.05-.06
Salsoda, bbl.....cwt.	.90-.95	.85-.95	1.10-1.20
Salt cake, bulk.....ton	17.00-18.00	17.00-18.00	17.00-19.00
Soda ash, light, 58%, bags, contract.....cwt.	1.38-.....	1.38-.....	1.38-.....
Dense, bags.....cwt.	1.45-1.55	1.45-1.55	1.45-1.55
Soda, caustic, 76%, solid, drums, contract.....cwt.	3.10-.....	3.10-.....	3.10-.....
Acetate, works, bbl.....lb.	.04-.05	.04-.05	.04-.05
Bicarbonate, bbl.....cwt.	2.00-2.25	2.00-2.25	1.75-2.00
Bichromate, casks.....lb.	.06-.06	.06-.06	.06-.06
Bisulphate, bulk.....ton	5.00-5.50	5.00-5.50	6.00-7.00
Bisulphite, bbl.....lb.	.03-.04	.03-.04	.04-.04
Chlorate, kegs.....lb.	.06-.06	.06-.06	.06-.06
Chloride, tech.....ton	12.00-14.75	12.00-14.75	12.00-14.00
Cyanide, cases, dom.....lb.	.18-.22	.18-.22	.19-.22
Fluoride, bbl.....lb.	.09-.09	.09-.09	.09-.09
Hyposulphite, bbl.....lb.	2.50-3.00	2.50-3.00	.02-.02
Nitrate, bags.....cwt.	2.36-.....	2.36-.....	2.50-.....
Nitrite, casks.....lb.	.08-.09	.08-.09	.09-.09
Phosphate, dibasic, bbl. lb.	.03-.03	.03-.03	.03-.03
Prussiate, yel. drums.....lb.	.10-.10	.10-.10	.10-.10
Silicate (30%, drums).....cwt.	.75-1.15	.75-1.15	.75-1.15
Sulphide, fused, 60-62%, dr. lb.	.03-.03	.03-.03	.02-.03
Sulphite, crys., bbl.....lb.	.03-.03	.03-.03	.02-.03
Strontium nitrate, bbl.....lb.	.08-.09	.08-.09	.09-.10
Sulphur, crude at mine, bulk. ton	19.00-.....	19.00-.....	15.00-16.00
Chloride, dr.....lb.	.05-.05	.05-.05	.04-.05
Dioxide, cyl.....lb.	.09-.10	.09-.10	.08-.09
Flour, bag.....cwt.	2.70-3.00	2.70-3.00	2.25-2.35
Tin bichloride, bbl.....lb.	.20-.20	.19-.....	.17-.....
Oxide, bbl.....lb.	.70-.....	.67-.....	.64-.....
Crystals, bbl.....lb.	.48-.....	.45-.....	.41-.....
Zinc chloride, gran., bbl. lb.	.07-.07	.07-.08	.06-.07
Carbonate, bbl.....lb.	.11-.11	.11-.11	.12-.14
Cyanide, dr.....lb.	.40-.41	.40-.41	.40-.41
Dust, bbl.....lb.	.09-.10	.09-.10	.08-.08
Zinc oxide, lead free, bag. lb.	.07-.07	.07-.07	.07-.07
5% lead sulphate, bags.....lb.	.07-.....	.07-.....	.06-.....
Sulphate, bbl.....cwt.	2.75-3.00	2.75-3.00	3.50-3.75

Oils and Fats

	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl.....lb.	\$0.12-\$0.13	\$0.12-\$0.13	\$0.16-\$0.17
Chinawood oil, bbl.....lb.	.17-.17	.16-.16	.13-.14
Coconut oil, Ceylon, tanks, N. Y.....lb.	.08-.10	.10-.....	.11-.....
Corn oil crude, tanks, (f.o.b. mill).....lb.	.08-.....	.10-.....	.09-.....
Cottonseed oil, crude (f.o.b. mill) tanks.....lb.	.07-.10	.10-.....	.09-.....
Linseed oil, raw, ear lots, bbl. lb.	11.00-.09	11.4-.....	14.0-.....
Palm, Lagos, casks.....lb.	.08-.08	.08-.09	.08-.....
Niger, casks.....lb.	.10-.10	.10-.11	.09-.....
Palm Kernel, bbl.....lb.	.11-.....	.13-.....	.14-.....
Peanut oil, crude, tanks (mill) lb.	.15-.15	.15-.15	.14-.....
Perilla, bbl.....gal.	.82-.85	.85-.90	1.00-1.02
Rapeseed oil, refined, bbl.....gal.	.10-.....	.10-.....	.15-.15
Sesame, bbl.....lb.	.10-.....	.10-.....	.11-.....
Soya bean tank (f.o.b. Coast) lb.	.08-.08	.08-.08	.08-.....
Sulphur (olive foots), bbl. gal.	.65-.66	.62-.65	.62-.63
Cod, Newfoundland, bbl. gal.	.65-.67	.65-.67	.76-.78
Menhaden, light pressed, bbl. gal.	.45-.....	.47-.....	.50-.....
Crude, tanks (f.o.b. factory) gal.			
Whale, crude, tanks.....lb.	.07-.07	.08-.....	.09-.09
Grease, yellow, loose.....lb.	.12-.....	.12-.....	.13-.....
Oleo stearine.....lb.	.10-.10	.10-.10	.11-.11
Red oil, distilled, d.p. bbl. lb.	.08-.....	.08-.....	.09-.....
Tallow, extra, loose.....lb.			

Coal-Tar Products

	Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl. lb.	\$0.60-\$0.65	\$0.60-\$0.65	\$0.60-\$0.62
Refined, bbl.....lb.	.85-.90	.85-.90	.75-.80
Alpha-naphthylamine, bbl. lb.	.35-.36	.35-.36	.35-.36
Aniline oil, drums, extra.....lb.	.16-.17	.16-.16	.17-.17
Aniline salts, bbl.....lb.	.22-.24	.20-.22	.20-.22
Anthracene, 80%, drums.....lb.	.60-.65	.60-.65	.65-.70
Benadikhyde, U.S.P., dr.....lb.	1.15-1.25	1.15-1.35	1.50-.....
Benadikhyde base, bbl.....lb.	.70-.72	.70-.75	.78-.84
Benzoic acid, U.S.P., kgs.....lb.	.58-.60	.58-.60	.75-.85
Benzyl chloride, tech, dr.....lb.	.25-.25	.25-.26	.35-.36
Benzoal, 90%, tanks, works. gal.	.24-.25	.25-.28	.24-.25
Beta-naphthol, tech., drums. lb.	.22-.24	.22-.24	.23-.25
Cresol, U.S.P., dr.....lb.	.18-.20	.18-.20	.23-.25
Cresylic acid, 97%, dr., wks. gal.	.59-.65	.59-.63	.59-.62
Diethylaniline, dr.....lb.	.31-.35	.31-.33	.33-.38
Dinitrophenol, bbl.....lb.	.17-.18	.17-.18	.18-.20
Dinitrotoluen, bbl.....gal.	.28-.30	.28-.30	.26-.28
Diphenylamine, bbl.....lb.	.45-.47	.48-.50	.48-.50
H-acid, bbl.....lb.	.63-.65	.63-.65	.70-.74

Coal-Tar Products—Continued

	Current Price	Last Month	Last Year
Naphthalene, flake, bbl. lb.	\$0.051-\$0.06	\$0.051-\$0.06	\$0.05-\$0.051
Nitrobenzene, dr. lb.	.09-.10	.09-.10	.09-.10
Para-nitraniline, bbl. lb.	.45-.48	.45-.50	.65-.67
Para-nitrotoluene, bbl. lb.	.28-.32	.28-.32	.40-.42
Phenol, U.S.P., drums. lb.	.17-.19	.17-.19	.22-.24
Picric acid, bbl. lb.	.30-.40	.30-.40	.25-.26
Pyridine, dr. lb.	3.60-.40	4.10-.40	4.10-4.20
R-salt, bbl. lb.	.47-.50	.40-.44	.50-.55
Resorcinol, tech. kegs. lb.	1.30-1.35	1.35-1.40	1.30-1.40
Salicylic acid, tech., bbl. lb.	.30-.32	.30-.32	.32-.33
Solvent naphtha, w.w., tanks, gal.	.35-.35	.35-.35	.26-.26
Tolidine, bbl. lb.	.95-.95	.95-.96	1.00-1.05
Toluene, tanks, works. gal.	.35-.35	.35-.35	.26-.26
Xylene, com., tanks. gal.	.36-.41	.36-.41	.26-.27

Miscellaneous

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl. ton	\$23.00-\$25.00	\$23.00-\$25.00	\$20.00-\$22.00
Casein, tech., bbl. lb.	.161-.161	.161-.181	.13-.14
China clay, powd., f.o.b. Va. ton	10.00-20.00	10.00-20.00	10.00-20.00
Imported, powd., ton	45.00-50.00	45.00-50.00	45.00-50.00
Dry colors:			
Carbon gas, black (wks.), lb.	.08-.081	.08-.081	.07-.071
Prussian blue, bbl. lb.	.32-.33	.32-.34	.34-.36
Ultramarine blue, bbl. lb.	.08-.35	.08-.35	.08-.35
Chrome green, bbl. lb.	.28-.30	.28-.30	.27-.29
Carmines red, tins. lb.	5.00-5.10	5.00-5.10	4.50-4.75
Para toner. lb.	.83-.90	.90-.95	.90-.95
Vermilion, English, bbl. lb.	1.45-1.50	1.45-1.50	1.35-1.40
Chrome yellow, C. P., bbl. lb.	.17-.18	.171-.18	.18-.19
Feldspar, No. 1 (f.o.b. N. C.) ton	5.50-6.50	6.00-6.50	5.50-6.00
Graphite, Ceylon, lump, bbl. lb.	.07-.091	.07-.091	.081-.09
Gun copal, Congo, bags. lb.	.091-.10	.091-.10	.08-.10
Manila, bags. lb.	.15-.18	.15-.16	.14-.16
Damar, Batavia, cases. lb.	.25-.251	.25-.26	.281-.281
Kauri, No. 1 cases. lb.	.55-.57	.57-.65	.58-.62
Kieselguhr (f.o.b. N. Y.) ton	50.00-55.00	50.00-55.00	50.00-55.00
Magnesite, calc. ton	44.00-.00	44.00-.00	40.00-41.00
Pumice stone, lump, bbl. lb.	.05-.07	.05-.08	.06-.08
Imported, casks. lb.	.03-.40	.03-.40	.03-.35
Rosin, H. bbl.	14.35-.00	15.85-.00	11.50-.00
Turpentine. gal.	.91-.93	.93-.98	.98-.00
Shellac, orange, fine, bags. lb.	.41-.42	.29-.30	.52-.53
Bleached, bonedry, bags. lb.	.49-.50	.36-.40	.59-.62
T. N. bags. lb.	.391-.40	.27-.28	.49-.51
Soapstone (f.o.b. Vt.), bags. ton	10.00-12.00	10.00-12.00	9.00-11.00
Talc, 200 mesh (f.o.b. Vt.) ton	11.00-.00	11.00-.00	10.50-.00
200 mesh (f.o.b. Ga.) ton	7.50-10.00	7.50-10.00	7.50-11.00
325 mesh (f.o.b. N. Y.) ton	14.75-.00	14.75-.00	14.75-.00
Wax, Bayberry, bbl. lb.	.31-.35	.21-.22	.20-.21
Beeswax, ref., light. lb.	.45-.46	.47-.48	.40-.42
Candelilla, bags. lb.	.34-.35	.34-.35	.30-.31
Carnauba, No. 1, bags. lb.	.56-.58	.50-.51	.37-.38
Paraffine, crude 105-110 m.p. lb.	.051-.06	.06-.061	.06-.00

Ferro-Alloys

	Current Price	Last Month	Last Year
Ferrotitanium, 15-18% ton	\$200.00-.00	\$200.00-.00	\$200.00-.00
Ferrochromium, 1-2% lb.	.23-.25	.23-.35	.24-.00
Ferromanganese, 78-82% ton	88.00-90.00	88.00-90.00	115.00-.00
Spiegelisen, 19-21% ton	32.00-34.00	32.00-34.00	32.00-.00
Ferrosilicon, 10-12% ton	33.00-38.00	33.00-38.00	39.50-43.00
Ferrotungsten, 70-80% lb.	1.05-.00	.95-1.11	.90-.00
Ferro-uranium, 35-50% lb.	4.50-.00	4.50-.00	4.50-.00
Ferrovanadium, 30-40% lb.	3.40-4.00	3.25-4.00	3.25-3.75

Non-Ferrous Metals

	Current Price	Last Month	Last Year
Copper, electrolytic. lb.	\$0.141-.00	\$0.141-.00	\$0.141-\$0.151
Aluminum, 96-99% lb.	.27-.28	.27-.28	.27-.28
Antimony, Chin. and Jap. lb.	.141-.15	.151-.16	.201-.00
Nickel, 99% lb.	.35-.00	.35-.00	.31-.32
Monel metal, blocks. lb.	.32-.33	.32-.33	.32-.33
Tin, 5-ton lots, Straits. lb.	.72-.00	.641-.00	.571-.00
Lead, New York, spot. lb.	8.35-.00	8.75-.00	.09-.00
Zinc, New York, spot. lb.	7.70-.00	7.80-.00	.071-.00
Silver, commercial. oz.	.54-.00	.631-.00	.631-.00
Cadmium lb.	.60-.00	.60-.00	.60-.00
Bismuth, 508-lb. lots. lb.	2.70-2.75	2.70-2.75	1.30-1.35
Cobalt. lb.	2.50-.00	3.00-.00	2.50-3.00
Magnesium, ingots, 99% lb.	.75-.80	.75-.80	.90-.95
Platinum, ref. oz.	112.00-.00	112.00-.00	117.00-.00
Palladium, ref. oz.	68.00-70.00	69.00-71.00	78.00-.00
Mercury, flask. 75 lb.	95.50-.00	90.50-.00	79.00-80.00
Tungsten powder. lb.	1.10-1.15	1.10-.00	.95-1.00

Ores and Semi-finished Products

	Current Price	Last Month	Last Year
Bauxite, crushed, wks. ton	\$5.50-\$8.50	\$5.50-\$8.50	\$5.50-\$8.75
Chrome ore, c.f. post. ton	22.50-25.00	22.50-24.00	18.50-24.00
Coke, dry, f.o.b. ovens. ton	3.75-4.25	3.75-4.25	4.75-5.00
Fluorspar, gravel, f.o.b. Ill. ton	18.00-.00	18.00-.00	17.50-18.50
Ilmenite, 52% TiO ₂ , Va. lb.	.011-.00	.011-.00	.011-.00
Manganese ore, 50% Mn., c.f. Atlantic Ports. unit	.40-.36	.35-.36	.42-.43
Molybdenite, 85% MoS ₂ per lb. MoS ₂ , N. Y. lb.	.50-.55	.50-.55	.60-.70
Monazite, 6% of ThO ₂ ton	120.00-.00	120.00-.00	120.00-.00
Pyrites, Span. fines, c.f. unit	.131-.00	.131-.00	.111-.12
Rutile, 94-96% TiO ₂ lb.	.12-.15	.12-.15	.12-.15
Tungsten, scheelite, 60% WO ₃ and over. unit	12.50-13.00	12.50-13.00	9.50-9.75
Vanadium ore, per lb. V ₂ O ₅ lb.	.30-.35	.30-.35	1.00-1.27
Zircon, 99% lb.	.03-.00	.03-.00	.06-.05

Current Industrial Developments

New Construction and Machinery Requirements

New England

Conn., Hartford—Hartford Falence Co., Falence St., manufacturers of porcelain, had plans prepared for the construction of a 2 story, 60 x 82 ft. factory. Estimated cost \$45,000. Buck & Sheldon, 60 Prospect St., are architects.

Conn., New Haven—Koppers Co., Union Trust Bldg., Pittsborough, Pa., is reported to have acquired 63 acres of land and plans the construction of a coal gas by-products plant here. Estimated cost approximately \$8,000,000.

Conn., New Haven—Yale University, is having plans prepared for the construction of a laboratory. Estimated cost \$200,000. H. C. Pelton, 415 Lexington Ave., New York, N. Y., is architect.

Conn., Stamford—City, F. B. Bartram, Chm. of School Commission, will receive bids until Oct. 25 for the construction of a school including physics and chemistry laboratories on Strawberry Hill. Estimated cost \$800,000. Knappe & Morris, 171 Madison Ave., New York, N. Y. Estimated cost \$800,000.

Mass., Boston—Boston Consolidated Gas Co., 149 Tremont St., awarded contract for the construction of a 1 story exhaustor house at 69 Cambridge St. to W. J. Bailey Co., 88 Broad St. Estimated cost \$40,000.

Mass., Cambridge (Boston P.O.)—Dewey & Almy Chemical Co., Harvey St., North Cambridge, is having preliminary plans prepared for the construction of a 2 story addition to plant. Estimated cost \$40,000. H. L. Kennedy, 80 Boylston St., Boston, is architect.

Mass., Charlestown (Boston P.O.)—W. F. Schrafft & Sons Corp., 160 Washington St. N., Boston, awarded contract for the construction of a 6 story, 200 x 480 ft. addition to factory and power house here, to Turner Construction Co., 178 Tremont St., Boston. Estimated cost \$1,500,000.

Mass., Dorchester (Boston P.O.)—Knox & Morse Co., 140 Oliver St., Boston, awarded contract for the construction of a 2 story, 50 x 100 ft. shellac factory on Freeport St. here to C. C. Temple Co., 99 Chauncy St., Boston. Estimated cost \$75,000.

Mass., Forest Hills (mail Boston) —Harvard University, c/o Stevens & Lee, 45 Newbury St., Boston, had revised plans prepared for the construction of a 2 story addition to anti-toxin laboratory. Estimated cost \$150,000.

Mass., Malden (Boston P.O.)—Malden & Melrose Gas Co., 200 Devonshire St., Bos-

ton, will build a 1 story gas purification plant on Commercial St. here. Estimated cost \$40,000. C. H. Tenney Co., 200 Devonshire St., Boston, Engr. will build by separate contracts.

Mass., Roxbury (Boston P.O.)—Chadwick-Boston Lead Co., 162 Congress St., Boston, awarded contract for the construction of 2 story, 65 x 110 ft. plant at 1 Southampton St. here to J. D. Marr, 384 Dorchester Ave., South Boston.

Mass., Waltham (Boston P.O.)—T. B. Plimpton, 200 Devonshire St., Boston, manufacturers of mica, awarded contract for the construction of a 1 story, 50 x 100 ft. addition to factory at 66 Woerd Ave. to A. A. Walsh, 24 Fiske Ave. Estimated cost \$40,000.

Chem. & Met. Weighted Index of Chemical Prices

Base = 100 for 1913-14

This month	114.17
Last month	113.59
October, 1925	112.79
October, 1924	111.10

Improved demand for chemicals has been reflected by a tendency toward higher prices and the weighted index number shows a gain of 58 points for the month. Higher prices ruled for alcohol, methanol, formaldehyde, sulphur products, and tin derivatives. Some of the coal-tar chemicals showed an easy trend and lead oxides sold at reduced levels.

Chem. & Met. Weighted Index of Prices for Oils and Fats

Base = 100 for 1913-14

This Month	135.71
Last month	142.25
October, 1925	158.21
October, 1924	142.31

Price changes for oils have been unusually drastic. The indicated record cotton crop brought out weakness in cottonseed oil and this in turn had a depressing effect on values for competing oils. Fats and greases also were adversely affected and sold off. The political situation in China has interfered with shipments of wood oil and the latter is bringing high prices.

Middle Atlantic

N. J., Bloomfield—Bakelite Corp., 230 Grove St., awarded contract for the construction of a 2 story factory on Grove St. to J. Jewkes & Sons, 676 Montgomery St., Jersey City. Estimated cost \$50,000.

N. Y., Brooklyn—Dept. of Public Welfare, Municipal Bldg., New York, awarded contract for the construction of a laboratory for Kings County Hospital to F. J. Cogswell, 50 Union Sq., New York.

N. Y., Buffalo—F. B. Davey, 52 West Falls St., Niagara Falls, manufacturer of tires, plans the construction of a plant. Estimated cost \$50,000.

N. Y., Buffalo—Dunlop Tire & Rubber Corp., River Road, have acquired 3½ acre site on Niagara River and plans the construction of a tire and rubber plant. Estimated cost to exceed \$1,000,000.

N. Y., Buffalo—Robins Conveying Belt Co., 15 Park Row, New York, has acquired the plant of the Hewitt Rubber Co. on Kensington Ave., here, and plans the construction of additions and extensions for rubber plant. Estimated cost \$300,000.

N. Y., Jordanville—Mohawk Limestone Products Co., L. A. Poston, awarded contract for the construction of a 55 x 60 and 52 x 80 ft. factory, to H. K. Ferguson Co., 4900 Euclid Ave., Cleveland, O. Estimated cost \$50,000.

N. Y., Pavilion—Genesee Valley Gas Co., Mount Morris, plans the construction of a gas plant here. Estimated cost to exceed \$150,000. R. C. Burdick, Mount Morris, is engineer.

Pa., Darlington—Darlington Fireproofing Co. plans the construction of a plant. Estimated cost \$100,000.

Pa., New Castle—Johnson Bronze Co. awarded construction of a 3 story, 45 x 153 ft. and 1 story, 50 x 153 ft. additions to plant, to H. K. Ferguson Co., 4900 Euclid Ave., Cleveland, O. Estimated cost \$100,000.

Pa., Oil City—Continental Refining Co. plans to expend \$150,000 for remodeling and enlarging refinery here.

Pa., Philadelphia—Charles Lennig & Co., Inc., Richmond and Kennedy Sts., awarded contract for the construction of a 1 story, 26 x 57 ft. addition to laboratory at Richmond and Bridge Sts., to Rumpf & Kohlmeier, 3538 North Broad St.

Pa., Philadelphia—National Carbon Co., Pier 6, North Port Richmond, awarded contract for the construction of a 1 story, 40 x 80 ft. plant to Central Contracting and Construction Co., Drexel Bldg.

Pa., Rouseville—The Pennzoll Co. awarded contract for the construction of a 1 story, 48 x 100 ft. addition to factory to Rust Engineering Co., 311 Ross St., Pittsburgh. Estimated cost \$40,000.

Pa., York—S. Morgan Smith Co. is in the market for a 96 in. cupola brass furnace, sand mixer and 25 ton reservoir ladle.

South

Ala., Birmingham—Alabama By Products Corp., American Trust Bldg., is reported to have plans under way for the construction of 49 additional Koppers ovens to have double capacity of present ones.

Ala., Birmingham—E. I. du Pont de Nemours, Wilmington, Del., has completed plans for the construction of a new dynamite manufacturing plant about ten miles from here, to contest of approximately 50 separate buildings including power units, machine shops, office buildings, etc. H. S. Stanton of the Du Pont Engineering Co., the builders, is construction superintendent.

Fla., Gainesville—University of Florida, P. K. Yonge, Chn., White House Hotel, will soon award contract for the construction of a 3 story, 145 x 204 ft. chemistry pharmacy building. R. Weaver is architect.

Ga., Sandersville—Georgia Portland Cement Co., Augusta, has acquired 400 acres of land and plans the construction of a cement plant near here, 3,000 to 5,000 lbs. daily capacity. Estimated cost \$3,000,000. Private plans.

Ky., Mayfield—Golden Key Milk Products Co., Washington Bldg., Madison, plans the construction of a 2 story, 120 x 150 ft. condenser. Estimated cost \$50,000. Architect not selected.

S. C., Charleston—J. F. Prettyman & Son, Summerville, plans the construction of a creosoting plant here. Estimated cost \$500,000. Modern equipment for commercial treating timber, etc., will be installed.

Tenn., Memphis—Cold Press Mills, 2250 Park Ave., has been granted permit to construct an oil mill. Estimated cost \$11,000.

Middle West

Ill., Ottawa—National Plate Glass Co. awarded contract for the construction of three pot furnaces for melting plate glass to William Swindell & Bros., Aspinwall, Pa. Estimated cost \$200,000.

Ind., Indianapolis—A. Stalnaker, c/o F. S. Cannon, 21 Virginia Ave., Archt., awarded contract for the construction of a 4 story, 22 x 195 ft. factory on South Meridian St. to Thompson & Binger, 922 Hume-Mansur Bldg. Estimated cost \$60,000. Hide Leather & Belting Co., 2227 South Meridian St., is lessee.

Mich., Detroit—Weston & Ellington, 150 Stroh Bldg., Archts. and Engrs., soon awards contract for the construction of a 2 story 60 x 190 ft. paint factory at Chicago and Detroit Terminal R.R. for Ditzler Color Co., 40 West Baltimore Ave. Owner is in the market for equipment for manufacture of paint.

Mich., Detroit—National Smelting & Refining Co., 1843 Livernois Ave., plans the construction of a 1 story, 60 x 200 and 70 x 150 ft. foundry for smelting and refining plant on Jefferson Ave. Estimated cost \$100,000. Murphy & Burns, 3456 Cass Ave., are engineers.

O., Akron—National Standard Co., Bettes Corners, manufacturers of rubber products, plans the construction of a 1 story, 70 x 280 ft. factory.

O., Cleveland—Otis Steel Co., E. J. Kulash, Pres., 3341 Jennings Rd., is having plans prepared for the construction of a 1 story, 84 x 160 ft. open hearth furnace. Estimated cost \$300,000. W. F. Hilditch, c/o owner, is architect. Cranes, ladles and door operators will be required.

O., Cleveland—The United Milk Products Co., C. L. Bartsche, Chn., 1252 Broadway, plans the construction of a 5 or 7 story milk plant. Estimated cost \$1,000,000. Architect not announced.

O., Cleveland—Willard Storage Battery Co., East 131st St. and Taft Ave., awarded contract for the construction of a 4 story, 135 x 212 ft. factory to H. K. Ferguson Co., 4900 Euclid Ave. Estimated cost \$300,000.

O., Fostoria—National Carbon Co., Inc., 30 East 42nd St., New York, awarded contract for the construction of an addition to plant here. Estimated cost \$1,000,000.

O., West Carrollton—Miami Paper Co., is having surveys made for extensions and improvements to plant. V. D. Simons, 431 North Michigan Ave., Chicago, Ill., is engineer.

Wis., Ashland—Menasha Printing & Carton Co., River St., awarded contract for the construction of a 1 story, 80 x 86 ft. addition to paper mill, to C. R. Meyer & Son Co., 50 State St., Oshkosh. Estimated cost \$50,000. Bleaching tanks and pumps will be required.

Wis., Eau Claire—Gillett Rubber Co., 799 Wisconsin St., awarded contract for the construction of a 1 story, 84 x 135 ft. addition to factory to Hoepfner-Bartlett Co., 414 East Grand Ave. Estimated cost \$50,000.

Wis., Milwaukee—J. Greenebaum Tanning Co., 337 West St., awarded contract for the construction of a 1 story, 52 x 175 ft. addition to tannery to Theo. Stark & Co., 130 Muskego Ave. Estimated cost \$40,000. Special tanning machinery will be required.

Wis., Milwaukee—Wesley Steel Treating Co., 651 South Pierce St., awarded contract for the construction of a 2 story, 30 x 78 ft. factory on South Pierce St. to United Builders, 128 Grand Ave. Estimated cost \$40,000. Heat treating furnaces will be installed.

Wis., Rhinelander—Rhinelander Paper Co., is having surveys made for extensions and improvements to plant. V. D. Simons, 431 North Michigan Ave., Chicago, Ill., is engineer.

West of Mississippi

Ia., Fort Dodge—Fort Dodge Serum Co., 600½ Central Ave., will build a 3 story, 47 x 80 ft. addition to serum plant by day labor.

Kan., Eureka—Eureka Glass Co. plans the construction of a factory. Estimated cost \$300,000.

Okla., Ponca City—Empire Gas & Fuel Co., plans the construction of a bone burner plant at refinery. Estimated cost \$65,000. Private plans.

Tex., Edinburg—Aransas Compress Co., Corpus Christi, manufacturers of by-prod-

ucts, is having plans prepared for the construction of a 1 and 2 story cotton oil mill. Estimated cost \$200,000. Private plans.

Tex., Mexia—Transcontinental Oil Co. has work under way on the construction of a 300 x 600 ft. casinghead gasoline plant at Nigger Creek oil fields near here. Estimated cost \$200,000. Private plans. Machinery will be installed.

Tex., Temple—Valley Cotton Oil Co., Waco, has acquired plants at Valley Mills and Temple, both plants will be combined and operated by owner. Estimated cost \$40,000. New machinery probably including new engine, crushers, etc., will be required.

Far West

Calif., Huntington Park (Los Angeles P. O.)—Foxon Pottery Co., 2300 East 52nd St., Los Angeles, has work under way on the construction of a 50 x 350 ft. factory here. Estimated cost \$100,000.

Calif., Los Angeles—Pioneer Paper Co., J. H. Plunkett, Gen. Mgr., 5500 South Alameda St., will build a 1 story, 60 x 200 ft. factory by day labor. Estimated cost \$125,000.

Calif., Pittsburgh—Pioneer Rubber Co., 353 Sacramento St., San Francisco, has work under way on the construction of a 1 story factory for the manufacture of belting and fire hose to increase the capacity, here. Estimated cost \$150,000.

Calif., Southgate (Los Angeles P. O.)—National Paper Products Co., 1789 Montgomery St., San Francisco, plans the construction of a 1 story paper factory, here.

Calif., Southgate (Los Angeles P. O.)—Zellerbach Paper Co., 220 South Los Angeles St., Los Angeles, is having plans prepared for the construction of the first unit to paper mill here. Estimated cost \$500,000.

Calif., Vernon—Illinois Pacific Glass Corp., 15th and Folsom Sts., San Francisco, has acquired a site and plans the construction of a branch plant here. Estimated cost \$750,000. New automatic glass making machinery will be installed.

Wash., Kelso—Pacific Wood Pulp Inc., recently incorporated, C. F. Schaub, Pres. Pacific Straw Paper & Board Co., A. T. Peterson and H. L. Copeland, Longview, incorporators, plans the construction of a pulp mill, 30 ton capacity here. Estimated cost \$375,000.

Wash., Longview—Longview Timber Co. is having plans prepared for the construction of a paper mill. Estimated cost \$2,500,000. Architect and engineer not announced.

Canada

Alta., Edmonton—Western Canada Pulp & Paper Co., F. M. McKee, Mgr., will soon receive bids for the construction of a plant for converting straw into paper. Estimated cost \$300,000.

B. C., Prince George—Prince George Pulp & Paper Co. Ltd., Vancouver, plans the construction of a new pulp and paper mill here. Estimated cost \$3,000,000.

B. C., Victoria—The Gallissano Wine Co. of Italy, I. Chazzi, Mgr., plans the construction of a wine making plant on Vancouver Island. Estimated cost \$150,000. New machinery and equipment will be required.

N. B., Campbellton—Canadian International Paper Co. Ltd., A. R. Graustein, Pres., Three Rivers, Que., plans the construction of a 350 ton paper mill on Restigouche River here. Estimated cost \$1,500,000.

N. B., St. Stephens—Hollingsworth & Whitney Co., 10 Post Office Sq., Boston, Mass., plans the construction of a pulp and paper mill on St. Croix River, also water power development. Estimated cost \$2,000,000.

Ont., St. Catharines—Muffets Ltd., Root Bldg., Buffalo, N. Y., is in the market for equipment for the manufacture of cereal products for proposed branch plant here. Estimated cost \$50,000. W. J. Morgan, c/o owner, is engineer.

Ont., Sault Ste. Marie—Spanish River Pulp & Paper Co., plans the installation of new electric pulp grinders, two steam turbine driven generators, etc., in pulp mill, also to rebuild boiler house and construct intake well. Estimated cost \$700,000.

Que., Pointe Aux Outardes—The Ontario Paper Co. Ltd., 13 McGee St., Montreal, has work underway on the construction of a pulp and paper mill here.